



## CRUISE REPORT<sup>1</sup>

**VESSEL:** *Hi'ialakai*, Cruise HI-08-09

**CRUISE PERIOD:** 12 September–12 October 2008

**AREA OF OPERATION:** Northwestern Hawaiian Islands (NWHI) (Fig. 1)

**TYPE OF OPERATION:** Personnel from the Coral Reef Ecosystem Division (CRED), Pacific Islands Fisheries Science Center, National Marine Fisheries Service (NMFS), NOAA, and their partner agencies conducted reef assessment/monitoring studies in waters surrounding the Northwestern Hawaiian Islands. All activities described in this report were covered by the following permit: PMNM-2008-062.

**ITINERARY:**

12 September Start of cruise. Embarked Peter Vroom (Chief Scientist), Jason Helyer (coral rapid ecological assessment [REA]), Stephanie Schopmeyer (coral REA), Cristi Richards (algae REA), Molly Timmers (invertebrate REA/Autonomous Reef Monitoring Systems [ARMS]), Russell Moffitt (ARMS/Data Manager), Elizabeth Keenan (ARMS/oceanography safety diver), Paula Ayotte (fish REA), Cori Kane (fish REA), Amanda Meyer (fish REA), Yumi Yasutake (fish REA), Benjamin Richards (fish towboard), Bonnie DeJoseph (fish towboard), Edmund Coccagna (benthic towboard), Jake Asher (benthic towboard), Ellen Smith (oceanography), Oliver Vetter (oceanography), Danny Merritt (oceanography), Kevin Lino (oceanography), Kerry Grimshaw (oceanography safety diver). Departed Pearl Harbor at 1030 and began transit to French Frigate Shoals (FFS) (~ 500 nmi). An introductory meeting was held for all scientific personnel and new crew members at 1300, followed by ship's drills.

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- 13 September Transit day. Jim Bostick (Dive Safety Officer) checked all scientist's dive gear and ran scientific personnel through injured diver drills. Edmund Coccagna reviewed contents of emergency medical kits with all scientific personnel. All dive gear was soaked in bleach solution as per Papahānaumokuākea Marine National Monument (PMNM) guidelines. Scientific personnel were briefed on the use of the HI-2 and avons.
- 14 September Arrived at French Frigate Shoals (FFS) at 1200. Conducted dive safety meeting and began launching small boats at 1230. The oceanography team swapped 1 Ecological Acoustic Recorder (EAR) and 3 Subsurface Temperature Recorders (STR) on the southern side of the atoll. The tow team completed two calibration tows along the SE forereef to test similarities between the two benthic and the two fish divers. The REA fish team successfully completed fish surveys at FFS-34 and FFS-12, but the benthic REA team was only able to complete surveys at FFS-34, leaving FFS-12 unsurveyed. At both FFS-34 and FFS-12, permanent transects were successfully relocated. The ARMS team deployed 3 ARMS at FFS-12.
- 15 September Continued work at FFS. The oceanography team swapped 4 STRs and deployed 1 Sea Surface Temperature (SST) buoy. One EAR was retrieved and a new instrument redeployed in an alternate location. One SST and one Coral Reef Early Warning System (CREWS) buoy plus its anchor were missing and not recovered. The tow team completed 6 tows along the N forereef and N backreef. The REA teams successfully relocated permanent transects and completed full surveys at FFS-H6, FFS-21, and FFS-30. The fish REA team also completed one additional survey at FFS-232. The ARMS team deployed 3 ARMS at FFS-H6.
- 16 September Continued work at FFS. The oceanography team conducted 12 shallow water Conductivity, Temperature and Depth (CTD) profiles, 3 shallow water nutrient (NUT) and chlorophyll (CHL) profiles, and 2 salinity samples. The tow team completed 6 tows (one incomplete) along the S and E forereefs. The benthic REA teams successfully located pins and completed full surveys at FFS-R29 and FFS-12. Full surveys were also conducted at FFS-25. The fish REA team surveyed sites FFS-R29, FFS-25, FFS-250, FFS-247, and FFS-248. The ARMS team deployed 3 ARMS at FFS-34. One deepwater CTD was conducted at French Frigate PS hi0611022 23.56667 -166.29967. Departed for Maro Reef.
- 17 September Transit day. Conducted two deepwater CTDs at Maro PS (24.99983, -169.00133) and Maro PS (25, -169.99933).

- 18 September Arrived at Maro Reef before dawn. The oceanography team deployed 1 new EAR and STR at MAR-R3, recovered the CREWS buoy and anchor replacing them with an SST buoy and anchor, with an STR on the anchor, and recovered and replaced one stand alone STR. Eight static CTD casts were conducted in conjunction with seawater carbonate chemistry sampling (only one strata was sampled). Two carbonate chemistry dives resulted in 8 seawater carbonate chemistry samples (to be analyzed for dissolved inorganic carbon (DIC) and total alkalinity ( $A_T$ ), 2 salinity samples, 2 nutrient samples, and 2 chlorophyll samples. The tow team completed 5 tows in the NW section of the reef. The REA teams relocated pins at sites MAR-R3 and MAR-R12 and completed full surveys. A full REA survey was also completed at MAR-R1. The fish REA team also conducted additional surveys at MAR-129, MAR-215, and MAR-528. The ARMS team deployed 3 ARMS at MAR-R1 and 3 ARMS at MAR-R12.
- 19 September Continued work at Maro Reef. The oceanography team conducted 11 shallow water vertical CTD casts around the reef and 12 static CTD casts in conjunction with seawater carbonate chemistry sampling. The combination of standard water quality samples that accompany some of the vertical CTD casts and the carbonate chemistry samples yielded 16 nutrient samples, 16 chlorophyll samples, 6 salinity samples, and 19 carbonate chemistry samples. Two stand alone STRs were recovered and replaced. The tow team completed 6 tows in the SE section of Maro Reef. The REA teams relocated permanent transects at MAR-08 and MAR-22 and completed full surveys. A full survey was also completed at MAR-32. The independent fish REA team also surveyed 5 sites: MAR-218, MAR-221, MAR-222, MAR-223, and MAR-537. The ARMS team deployed 3 ARMS at MAR-22. One deepwater CTD occurred at Laysan PS hi0611005 25.56567 -171.53367. Departed for Laysan Island.
- 20 September Arrived Laysan Island pre-dawn; contacted field camp personnel to inform them that the oceanography team would be walking below the high tide line to retrieve one of the STRs. The oceanography team retrieved 1 SST anchor, swapped out 3 STRs, and conducted 7 vertical CTD casts that yielded 9 nutrient samples and 9 chlorophyll samples. The tow team completed 5 tows, completely circumnavigating the island. The REA teams relocated permanent transect pins at LAY-05, LAY-R9, and LAY-12 and completed a full complement of REA surveys. The fish REA teams also completed surveys at LAY-128, LAY-210, LAY-211, LAY-212,

LAY-213, LAY-214, LAY-816, and LAY-820. Departed for Pearl and Hermes Atoll.

- 21 September Transit day.
- 22 September Arrived Pearl and Hermes Atoll before dawn. The oceanography team replaced one CREWS buoy and associated anchor with an SST and new anchor. An STR at this same site was retrieved and replaced. One Ocean Data Platform (ODP) was retrieved and replaced, and 4 STRs (in addition to the one previously mentioned) were collected and replaced. The tow team completed 5 tows along the SW forereef, and 1 tow on the SW backreef. Bleaching of Montiporid corals was reported during this backreef tow. The REA team located permanent transects at PHR-R42 and PHR-31 and completed full surveys. A full survey was also completed at PHR-34. The fish REA team also conducted a fish survey at PHR-192. Three ARMS were deployed at PHR-R42.
- 23 September Continued work at Pearl and Hermes Atoll. The oceanography team deployed 1 EAR, retrieved and deployed 6 STRs, and conducted 9 CTD casts that yielded 6 chlorophyll and 6 nutrient samples. The towed-diver team completed 6 tows: 5 along the N to NE forereef, 1 along the N backreef. The REA team successfully located permanent transect pins at PHR-24, PHR-R39, and PHR-R44. Full REA surveys were completed at each site. The fish REA teams also completed surveys at PHR-115, PHR-119, PHR-175, PHR-179, PHR-181, PHR-185, PHR-194. ARMS were deployed at PHR-R26.
- 24 September Continued work at Pearl and Hermes Atoll. The oceanography team conducted 14 CTD casts that yielded 12 nutrient, 12 chlorophyll, and 2 salinity samples. Four STRs were retrieved and replaced. The towed-diver team completed 5 tows along the E to SW forereef. The REA team located pins at PHR-R26 and PHR-R31 and completed full surveys. A full survey was also completed at PHR-R32. The fish REA team conducted additional surveys at PHR-117, PHR-118, PHR-176, PHR-183, PHR-184, PHR-188, PHR-191. ARMS were deployed at PHR-R31. Departed for Midway Atoll.
- 25 September Arrived at Midway Atoll. The oceanography team deployed 1 EAR and associated STR and deployed 1 SST with associated anchor and STR. The old SST anchor was retrieved, but the SST was missing. Six additional STRs were recovered and 4 new ones deployed. Two DIC sites were visited where 5 CTDs were conducted that yielded 8 DIC samples, 2 salinity samples, 2



chlorophyll samples, and 2 nutrient samples. The towed-diver team completed 5 tows along the eastern forereef. The REA teams located permanent transect pins at MID-R3 and MID-R7 and completed full surveys. An additional complete survey was conducted at MID-H10. The fish team completed additional surveys at PHR-107 and PHR-109. Three ARMS were installed at both MID-R3 and MID-R7.

- 26 September Continued work at Midway Atoll. The oceanography team deployed two WTRs, 1 Aquadop, and associated anchors. They then conducted 3 DIC profiles with 3 CTDs that yielded 12 DIC samples, 3 chlorophyll samples, 3 nutrient samples, and 3 salinity samples. The towed-diver team completed 5 tows along the W forereef, and 1 tow in the W lagoon. The REA teams relocated permanent transect pins at MID-01, MID-H11, and MID-H21 and completed full REA surveys at each site. The fish REA team conducted additional surveys at MID-156, MID-161, MID-164, MID-165, and MID-170. ARMS were installed at MID-H11.
- 27 September Midway Atoll. Nonworking day.
- 28 September Continued work at Midway Atoll. The oceanography team recovered and deployed 1 ODP, and swapped out a WTR. They conducted 7 CTDs and 2 water samples that yielded 10 chlorophyll samples, 10 nutrient samples, and 1 salinity sample. The tow team completed 5 lagoonal tows and targeted the reported algal bloom to try and get an estimate of its extent. The REA team relocated permanent transect pins at MID-02, MID-03, and MID-R20. Full REA surveys were completed at each site. ARMS were deployed at MID-02. Departed for Kure Atoll.
- 29 September Arrived at Kure Atoll before dawn. The oceanography team recovered 1 EAR and associated anchor, and 1 CREWS buoy and associated anchor. An SST buoy was recovered and a new one deployed. An STR was retrieved off the CREWS anchor and a new STR deployed on the SST anchor. Two additional STRs were recovered and deployed. The tow team completed 5 tows: 3 along the NW forereef, 2 in the NW backreef. The REA team relocated permanent pins at KUR-18, KUR-R33, and KUR-R36, and full surveys were conducted at each site. The fish REA team completed additional surveys at KUR-104 and KUR-149. ARMS were deployed at KUR-18 and KUR-R33.
- 30 September Continued work at Kure Atoll. People from the field camp came aboard to pick up supplies, receive medical attention, and drop off samples of the algal bloom. The oceanography team recovered 2

WTRs and 2 STRs. One STR was deployed. They also conducted 12 CTDs and 4 water samples that yielded 12 chlorophyll samples, 12 nutrient samples, and 2 salinity samples. The towed-diver team completed 5 forereef tows moving counterclockwise from the S to NE and 1 central lagoon tow close to KUR-18. The REA team successfully located permanent transect pins at KUR-02, KUR-12, and KUR-R35 and completed full surveys at each site. The fish REA team also surveyed KUR-102, KUR-105, KUR-106, KUR-147, KUR-154, and KUR-379. ARMS were deployed at KUR-02 and KUR-12.

- 1 October Continued work at Kure Atoll. The oceanography team deployed 2 WTRs and 1 STR and conducted 1 CTD and 1 water sample that yielded 3 chlorophyll samples and 3 nutrient samples. The oceanography also collected samples of the algal bloom. The tow team completed 3 tows in backreef and lagoonal areas. The REA teams located permanent transects at KUR-09, KUR-14 and completed full surveys. A complete survey was also conducted at KUR-17. The fish REA team also completed surveys at KUR-103, KUR-141, KUR-145, KUR-148, and KUR-301. The Chief Scientist accompanied people from the Green Island field camp on a tour around the island to view mats of algae from the algal bloom washed up on the beach and snorkeled on patch reefs covered by the invasive alga. Departed for Pearl and Hermes Atoll.
- 2 October Arrived at Pearl and Hermes Atoll at 0700. The oceanography team recovered and deployed 3 STRs and conducted 6 CTDs (1 every hour) and 6 water samples (30 m depth) close to the ODP site that yielded 6 chlorophyll samples and 6 nutrient samples. The towed-diver team completed 5 tows in the W and S portions of the atoll: 3 forereef and 2 backreef. The REA team located pins at PHR-22, PHR-32, and PHR-33 but were unable to locate the pins at PHR-30. Six new pins were installed at PHR-30. Full surveys were completed at each site. The fish REA team also completed surveys at PHR-122, PHR-173, PHR-174, PHR-177 and PHR-198. ARMS were installed at PHR-33.
- 3 October Continued work at Pearl and Hermes Atoll. The oceanography team conducted a temporal CTD characterization to monitor possible upwelling close to the ODP site. Seven CTD casts and 8 water samples (1 was a duplicate) occurred and yielded 8 chlorophyll samples, 8 nutrient samples, and 2 salinity samples. The towed-diver team completed 5 tows: 1 along the NW forereef, 4 along the N backreef. The REA team relocated permanent transect pins at PHR-23 and PHR-26 and completed full REA surveys at each site. The REA team also visited one new site,

	<p>PHR-35. Additional fish REA surveys occurred at PHR-116, PHR-121, and PHR-187. ARMS were deployed at PHR-23. Departed for Lisianski Island.</p>
4 October	<p>Arrived at Lisianski Island at 0700. The oceanography team recovered 2 WTRs, deployed 1 WTR, recovered 1 SST anchor (buoy was missing), deployed 1 SST buoy and associated anchor, recovered and deployed 4 STRs, and deployed 1 EAR with associated anchor. The towed-diver team completed 6 tows around the northern portion of the island. The REA teams relocated permanent transect pins at LIS-12, LIS-R14, and LIS-18 and completed full surveys. ARMS were installed at LIS-R14 and LIS-18. Conducted a deepwater CTD at the historical Lisianski site.</p>
5 October	<p>Continued work at Lisianski Island. The oceanography team deployed 1 WTR, recovered and deployed 1 STR, conducted 19 CTDs and 4 water samples that yielded 18 chlorophyll samples, 18 nutrient samples, and 1 salinity sample. The towed-diver team completed 6 tows along the SE side of Neva Shoals. The REA teams relocated pins at LIS-R7, LIS-10, and LIS-R10 and conducted full surveys. Additional fish REA surveys were completed at LIS-126, LIS-201, LIS-202, LIS-203, LIS-208, LIS-209, LIS-502, and LIS-514. ARMS were deployed at LIS-R10. Departed for French Frigate Shoals.</p>
6 October	<p>Transit day.</p>
7 October	<p>Conducted Gardner Pinnacle deepwater CTD at 0400 and a French Frigate Shoals deepwater DIC sample at 1130. Arrived at French Frigate Shoals at 1300. The oceanography team visited 2 DIC sites and took 8 DIC samples that yielded 2 chlorophyll samples, 2 nutrient samples, and 2 salinity samples. The towed-diver team completed 2 tows to the E and NE of La Perouse Pinnacle. The REA teams completed a full survey at FFS-35. The fish REA teams also completed surveys at FFS-235 and FFS-252. ARMS were installed at FFS-35.</p>
8 October	<p>Continued work at French Frigate Shoals. The oceanography team recovered and deployed 1 STR and conducted 4 DIC dives that resulted in 16 DIC samples that yielded 4 chlorophyll samples, 4 nutrient samples, and 4 salinity samples. The towed-diver team completed 6 tows along the N and E forereef. The REAs completed full surveys at FFS-22, FFS-29, and FFS-33. Permanent transect pins were found at FFS-33. The fish REA team conducted additional surveys at FFS-226, FFS-228, FFS-229,</p>

FFS-234, FFS-235, FFS-241, FFS-243. ARMS were installed at FFS-33.

- 9 October Continued work at French Frigate Shoals. The oceanography team visited 2 DIC sites that resulted in 10 DIC samples that yielded 2 chlorophyll samples, 2 nutrient samples, and 2 salinity samples. The towed-diver team completed 4 tows on the N backreef. Two of these tows consisted of both benthic and fish divers, the other two tows were benthic calibration dives. The REA teams relocated pins at FFS-32 and FFS-R46. Full surveys were completed at these sites as well as at FFS-R30. The fish REA teams also completed surveys at FFS-136, FFS-138, FFS-240, FFS-242, and FFS-244. ARMS were installed at FFS-32.
- 10 October Transit day.
- 11 October Transit day.
- 12 October Arrived in Honolulu. Disembarked Vroom, Helyer, Schopmeyer, Richards, Timmers, Moffitt, Keenan, Ayotte, Kane, Meyer, Yasutake, Richards, DeJoseph, Coccagna, Asher, Smith, Vetter, Merritt, Lino, and Grimshaw. End of cruise.

Table 1: Cruise statistics for NWHI RAMP 2008.

	French Frigate Shoals	Maro Reef	Laysan Island	Pearl and Hermes Atoll	Midway Atoll	Kure Atoll	Lisianski Island/ Neva Shoals	Gardner Pinnacle	Mokumanamana (Necker Island)	Total
Towed Diver Habitat/Fish Surveys	24	11	5	27	16	14	12	-	-	109
Towed Diver Habitat Diver Calibration Tows	2	-	-	-	-	-	-	-	-	2
Combined tow lengths (km)	56	23	12	63	39	32	25	-	-	250
Fish Rapid Ecological Assessments	32	14	11	39	16	22	14	-	-	148
Benthic Rapid Ecological Assessments	14	6	3	13	9	9	6	-	-	60
Autonomous Reef Monitoring Systems (ARMS) deployed	18	9	0	15	12	12	9	-	-	75
Ecological Acoustic Recorders (EAR) Recovered	2	0	0	0	0	1	0	-	-	3
EARs Deployed	2	1	0	1	1	1	1	-	-	7
Wave and Tide Recorders (WTR) Recovered	0	0	0	0	0	2	2	-	-	4
WTRs Deployed	0	0	0	0	2	2	2	-	-	6
AquaDopps Deployed	0	0	0	0	1	0	0	-	-	1
Ocean Data Platforms (ODP) Recovered	0	0	0	1	1	0	0	-	-	2
ODPs Deployed	0	0	0	1	1	0	0	-	-	2
Sea Surface Temperature (SST) buoys recovered	0	0	1*	0	1*	1*	1*	-	-	0
*anchor recovered without SST buoy										0
SST buoys deployed	1	1	0	1	1	1	1	-	-	6
Subsurface Temperature Recorders (STR) recovered	8	5	3	17	6	6	5	-	-	50
STRs deployed	8	5	3	19	6	6	5	-	-	52
Coral Reef Early Warning System (CREWS) buoys recovered	0	1	0	1	0	1	0	-	-	3
*anchor recovered without CREWS buoy										3
CREWS buoys deployed	0	0	0	0	0	0	0	-	-	0
Deepwater CTDs (from <i>Hi`ialakai</i> )	3	2	1	1	3	1	1	1	1	14
Discrete nutrient (NUT) and chlorophyll (CHL) water samples collected in conjunction with deep water CTDs	30	20	10	10	30	10	10	10	10	140

	French Frigate Shoals	Maro Reef	Laysan Island	Pearl and Hermes Atoll	Midway Atoll	Kure Atoll	Lisianski Island/Neve Shoals	Gardner Pinnacle	Mokumanamana (Necker Island)	Total
Discrete carbonate chemistry water samples collected in conjunction with deep water CTDs	7	5	2	3	7	2	2	3	2	33
Discrete salinity samples (SAL) collected in conjunction with deep water CTDs	1	1	1	1	1	1	1	1	1	9
Shallow water (30m) CTD Casts (from small boats)	12	11	7	34	7	13	19	-	-	103
Discrete NUT and CHL water samples collected in conjunction with shallow water CTDs	24	26	28	68	20	42	36	-	-	244
Discrete carbonate chemistry water samples collected in conjunction with shallow water CTDs	9	7	0	0	0	0	0	-	-	16
Discrete salinity (SAL) samples collected in conjunction with shallow water CTDs	2	3	0	2	1	2	1	-	-	11
Benthic habitat carbonate chemistry static (non-profiling mode) CTD casts	32	20	0	0	8	0	0	-	-	60
Benthic habitat discrete carbonate chemistry water samples collected in conjunction with benthic carbonate chemistry CTDs	34	20	0	0	20	0	0	-	-	74
Benthic habitat discrete NUT and CHL water samples collected in conjunction with benthic carbonate chemistry CTDs	16	10	0	0	10	0	0	-	-	36
Benthic habitat discrete SAL water samples collected in conjunction with benthic carbonate chemistry CTDs	8	5	0	0	5	0	0	-	-	18
SCUBA dives	245	109	55	232	117	116	109	-	-	983

Table 2: Small boat fuel consumption for NWHI RAMP 2008. Total km traveled and load carried are estimates.

		FFS				Maro			Laysan			PHR			Midway			Kure			PHR			Lisianski			FFS		
Dates surveyed		9/14	9/15	9/16	9/18	9/19	9/20	9/22	9/23	9/24	9/25	9/26	9/28	9/29	9/30	10/1	10/2	10/3	10/4	10/5	10/7	10/8	10/9						
Fuel used	Safeboat	9	14	29	16	29.5	Est. 3	23	17.5	24.5	10	13	4	27	14.7	17	19.4	25	15	18.6	6	13.5	10.5						
	Steeltoe	9	15	41	17	27	17.5	13	24	27	19	10	27	18.1	23	18.7	21	19	17	29.2	6	35.6	16						
	Avon	Est. 6.5	Est. 6.5	Est. 6.5	Est. 6.5	Est. 6.5	Est. 6.5	Est. 6.5	4	5	6	6	6	6	6	6	6	6	6	6	3	6	6						
	Zodiac	Est. 6.5	Est. 6.5	Est. 6.5	Est. 6.5	Est. 6.5	Est. 6.5	Est. 6.5	6.5	5 (+3)	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	3.5	6.5	6.5					
Conditions	Total km traveled (steeltoe)	25	75	100	50	100	50	60	100	55	45	45	50	40	75	60	60	50	45	85	40	115	20						
	Load carried (in lb; steeltoe)	1575	1825	875	3325	1325	1575	3325	1695	1445	2195	1945	1445	2945	1695	1445	1445	1445	1695	1445	1445	1775	1445						
	Total km traveled (safeboat)	40	40	60	60	60	18	62	52	80	27	30	30	50	40	50	60	75	50	45	n/a	65	70						
	Load carried (in lb; safeboat)	1375	1375	1375	1375	1375	1375	1375	1375	1375	1375	1375	1375	1375	1375	1375	1375	1375	1375	1375	1375	1375	1375						
	Total km traveled (avon)	n/a	22	37	25	33	11	n/a	30	33	33	17	n/a	n/a	40	30	30	20	n/a	17	16	40	22						
	Load carried (in lb; avon)	n/a	880	900	900	900	900	n/a	900	880	900	1020	n/a	n/a	900	900	900	900	n/a	900	900	900	900						
	Total km traveled (zodiac)	26	41	28	28	29	14	43	37	33	24	30	n/a	n/a	40	30	30	40	17	25	10	25	35						

Load carried (in lb; zodiac)	970	900	890	890	890	900	930	900	890	900	900	n/a	n/a	900	900	900	900	900	900	900	900	900
Swell height (ft)	1.3	1.8	2.2	1.6	2.4	1.4	1.6	2.3	2.3	2.0	0.0	4.0	3.0	2.5	2.9	3.5	3.3	2.5	2.6			
Swell direction	275	145	90	30	125	130	190	280	155	150		70	20	140	150	110	150	120	130			
Wave height (ft)	0	0	1	0	0	0	0	0	0	0	1	3	3	2	0	3	1	2	1			
Wind direction	215	90	70	70	100	140	180	145	50	30	120	65	83	125	100	125	165	108	125			
Wind speed (kn)	5	5	10	6	4	3	6	5	2	6	13	19	19	9	5	11	12	10	7			
Total gal used	31	42	83	46	69.5	33.5	49	52	64.5	41.5	35.50	43.50	57.6	50.2	48.2	52.9	56.5	44.5	60.3	18.5	61.6	39
Cumulative gal used	31	73	156	202	271.5	305	354	406	470.5	512	547.50	591.00	648.6	698.8	747	799.9	856.4	900.9	961.2	979.7	1041.3	1080.3
km/gal (steeltoe)	2.78	5.00	2.44	2.94	3.70	2.86	4.62	4.17	2.04	2.37	4.50	1.85	2.21	3.26	3.21	2.86	2.63	2.65	2.91	6.67	3.23	1.25
km/gal (safeboat)	4.44	2.86	2.07	3.75	2.03	6.00	2.70	2.97	3.27	2.70	7.50	1.11	3.40	2.72	2.94	3.09	3.00	3.33	2.42	n/a	4.81	6.67
km/gal (avon)	n/a	3.38	5.69	3.85	5.08	1.69	n/a	7.50	6.60	5.50	2.83	n/a	n/a	6.67	5.00	5.00	3.33	n/a	2.83	5.33	6.67	3.67
km/gallon (zodiac)	4.00	6.31	4.31	4.31	4.46	2.15	6.62	6.62	4.13	3.69	4.62	n/a	n/a	6.15	4.62	4.62	6.15	2.62	3.85	2.86	3.85	5.38
km/gal/lb (steeltoe)	1.76E-03	2.74E-03	2.79E-03	8.85E-04	2.80E-03	1.81E-03	1.39E-03	2.46E-03	1.41E-03	1.08E-03	2.31E-03	1.28E-03	7.50E-04	1.92E-03	2.22E-03	1.98E-03	1.82E-03	1.56E-03	2.01E-03	4.61E-03	1.82E-03	8.65E-04
km/gal/lb (safeboat)	3.23E-03	2.08E-03	1.50E-03	2.73E-03	1.48E-03	4.36E-03	1.96E-03	2.16E-03	2.38E-03	1.96E-03	5.45E-03	8.08E-04	2.47E-03	1.98E-03	2.14E-03	2.25E-03	2.18E-03	2.42E-03	1.76E-03	n/a	3.50E-03	4.85E-03
km/gal/lb (avon)	n/a	3.85E-03	6.32E-03	4.27E-03	5.64E-03	1.88E-03	n/a	8.33E-03	7.50E-03	6.11E-03	2.78E-03	n/a	n/a	4.85E-03	3.64E-03	3.64E-03	2.42E-03	n/a	2.06E-03	5.93E-03	7.41E-03	4.07E-03
km/gal/lb (zodiac)	4.12E-03	7.01E-03	4.84E-03	4.84E-03	5.01E-03	2.39E-03	7.11E-03	7.36E-03	4.64E-03	4.10E-03	5.13E-03	n/a	n/a	6.84E-03	5.13E-03	5.13E-03	6.84E-03	2.91E-03	4.27E-03	3.17E-03	4.27E-03	5.98E-03



## **MISSIONS:**

- A. Conduct ecosystem monitoring of the species composition, abundance, percent cover, size distribution, and general health of the fish, corals, other invertebrates, and algae of the shallow water (< 35 m) coral reef ecosystems of the Northwestern Hawaiian Islands.
- B. Deploy an array of CREWS buoys, SST buoys, subsurface ODPs, subsurface WTRs, and STRs to allow remote long-term monitoring of oceanographic and environmental conditions affecting coral reef ecosystems of the Northwestern Hawaiian Islands.
- C. Collect water samples for analysis of nutrient and chlorophyll levels.
- D. Conduct shipboard CTDs to a depth of 500 m, shallow water CTDs from small boats to a depth of ~ 30 m, and shipboard ADCP surveys around reef ecosystems to examine physical and biological linkages supporting and maintaining these island and atoll ecosystems.
- E. Determine the existence of threats to the health of these coral reef resources from anthropogenic sources, including marine debris.
- F. Collect ADCP data during all transits. The ADCP unit shall be configured to collect narrow-band data in 16-meter bins (deepwater mode).

## **RESULTS:**

See Appendices B Through H.

## **SCIENTIFIC PERSONNEL:**

Peter Vroom, Ph.D., Chief Scientist, Data Management Team, University of Hawaii (UH)-Joint Institute for Marine and Atmospheric Research (JIMAR), Pacific Islands Fisheries Science Center (PIFSC)-Coral Reef Ecosystems Division (CRED)

Jason Helyer, Coral Rapid Ecological Assessment (REA) Team, UH-JIMAR, PIFSC-CRED

Stephanie Schopmeyer, Coral REA Team, UH-JIMAR, PIFSC-CRED

Cristi Richards, Algae REA Team, UH-JIMAR, PIFSC-CRED

Molly Timmers, Invertebrate REA Team, Autonomous Reef Monitoring Systems (ARMS) Team, UH-JIMAR, PIFSC-CRED

Russell Moffitt, ARMS Team, Data Management Team, UH-JIMAR, PIFSC-CRED

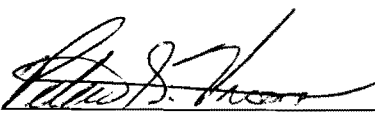
Elizabeth Keenan, ARMS Team, Oceanography Safety Diver, NOAA  
Papahānaumokuākea Marine National Monument (PMNM)


Paula Ayotte, Fish REA Team, UH-JIMAR, PIFSC-CRED  
Cori Kane, Fish REA Team, State of Hawaii, Division of Aquatic Resources  
Amanada Meyer, Fish REA Team, State of Hawaii, Division of Aquatic Resources  
Yumi Yasutake, Fish REA Team, PMNM  
Bonnie De Joseph, Towed Diver Team – Fish, UH-JIMAR, PIFSC-CRED  
Benjamin Richards, Towed Diver Team – Fish, UH-JIMAR, PIFSC-CRED  
Jacob Asher, Towed Diver Team – Habitat, UH-JIMAR, PIFSC-CRED  
Edmund Coccagna, Towed Diver Team – Habitat, UH-JIMAR, PIFSC-CRED  
Ellen Smith, Oceanography, UH-JIMAR, PIFSC-CRED  
Daniel Merritt, Oceanography, UH-JIMAR, PIFSC-CRED  
Oliver Vetter, Oceanography, UH-JIMAR, PIFSC-CRED  
Kevin Lino, Oceanography, UH-JIMAR, PIFSC-CRED  
Kerry Grimshaw, Oceanography, UH-JIMAR, PIFSC-CRED

### **DATA COLLECTED:**

Digital images from photoquadrats  
Algal voucher specimens necessary for algal species identification  
Benthic Line Point Intercept data  
Number of coral colonies, by species, within belt transects of known area, and overall coral colony density at each site  
Qualitative assessment (DACOR) of coral species' relative abundance at each site  
Size class distributions of corals (by species and overall) at each site  
Digital images of diseased coral  
Field notes on signs of coral bleaching or disease  
Samples of diseased coral for histopathological analysis  
Density counts of targeted organisms within belt transects  
Urchin test size diameters  
Installation of ARMS to eventually provide an index of biodiversity  
Digital images of non-coral marine invertebrates  
Samples of targeted species undergoing genetic connectivity work throughout the Hawaiian Archipelago  
Digital still photos of overall site character and typical benthos at each site  
Transect surveys of all fish 1 cm or larger in 600 m<sup>2</sup> – ID to species and estimate size  
Fish species presence checklists for community diversity estimates at each site  
Digital images of rare or interesting fish species  
Digital images of the benthic habitat from towboard surveys  
Macroinvertebrate counts from towboard surveys  
Quantitative surveys of reef fishes (larger than 50 cm TL) to species level from towboards  
Habitat lineation from towboard surveys  
Benthic composition estimations from towboard surveys  
Acoustic Doppler Current Profile (ADCP) data

Shipboard Conductivity, Temperature and Depth (CTD) profiles to 500 m with fluorometer attached  
Water Samples to 500 m: Chlorophyll and Nutrients – 5 depths per cast, carbonate chemistry – 2 depths per cast  
Shallow water Conductivity, Temperature, Depth (CTD) casts: 30 m with transmissometer and dissolved oxygen sensor attached  
Shallow Water Samples (30 m): Chlorophyll and Nutrients – 4 depths per cast, carbonate chemistry – 2 depths per cast  
Benthic carbonate chemistry sampling  
Sea surface and subsurface temperature at variable depths  
Sea surface and subsurface salinity at variable depths  
Spectral wave energy and tidal elevation  
Directional ocean currents  
Solar radiation, air temperature, wind speed and direction, turbidity, and photosynthetic active radiation  
Shipboard Acoustic Doppler Current Profiler (SADCP) transects  
Ecological Acoustic Recorder (EAR) data

Submitted by:   
Peter S. Vroom, Ph.D.  
Chief Scientist

Approved by:   
Kacky Andrews  
Program Manager  
Coral Reef Conservation Program

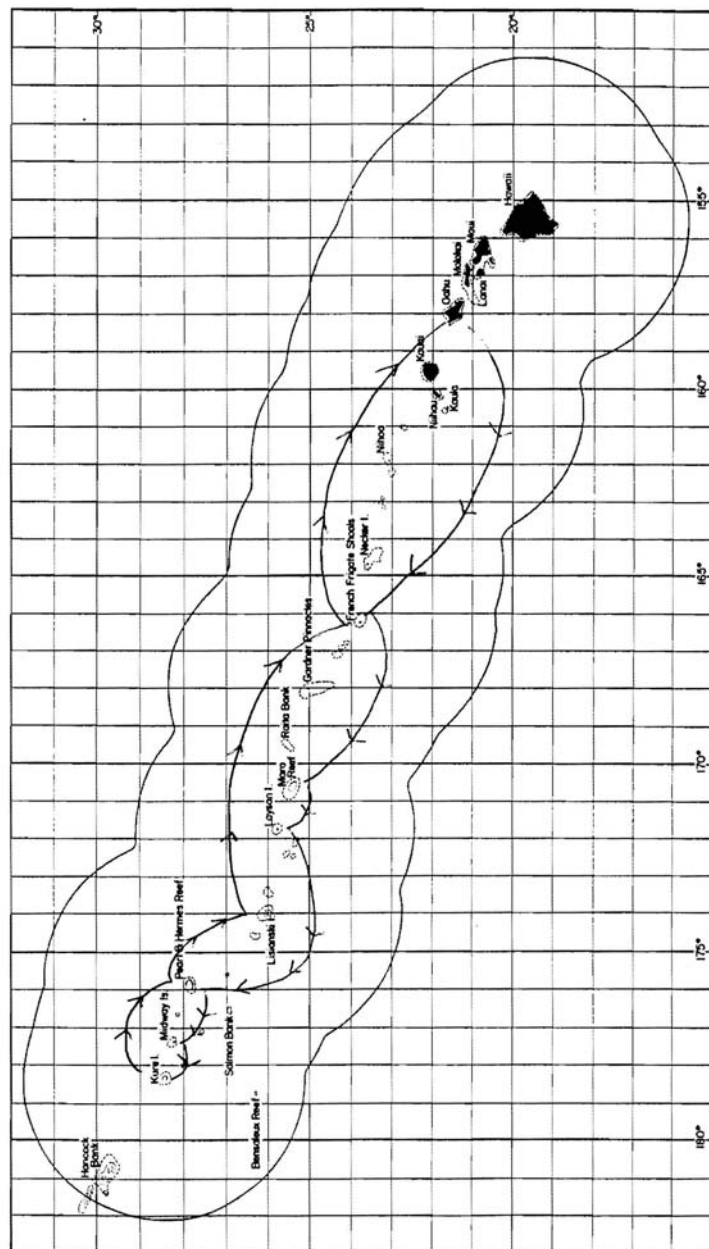


Figure 1.--Track of the *Hi'ialakai* HI-08-09, September 12 through October 12, 2008.

## **Appendix A: Methods**

### A.1 Oceanography and Water Quality Methods

*(Oliver Vetter, Daniel Merritt, Ellen Smith, Kevin Lino, Kerry Grimshaw)*

The Coral Reef Ecosystem Division has been conducting multidisciplinary research in the Northwestern Hawaiian Islands since 2000. Considering that the oceanographic component of this research has been well established, the recovery/redeployment of instrument platforms and the continuation of oceanographic measurements represent ongoing monitoring and assessment of the island. During HI0809, the oceanography team utilized both established and new methods to monitor long-term trends and assess oceanographic conditions.

Long-term oceanographic monitoring and assessment is accomplished by deployment and retrieval of a variety of internally recording and near real-time telemetered instrument platforms. These instruments include:

- Coral Reef Early Warning System (CREWS) buoys: Surface buoys which measure solar radiation, air temperature, wind speed and direction, sea surface temperature, salinity, turbidity, and (on enhanced models) photosynthetic active radiation. CREWS buoys telemeter a portion of their collected data in near real time.
- Sea Surface Temperature (SST) buoys: Measure and internally record high resolution surface water temperature and telemeter a subset of collected data in near real time.
- Wave and Tide Recorders (WTR): Measure surface gravity waves, tides and subsurface water temperature.
- Ocean Data Platforms (ODP): Moored instruments which measure subsurface temperature, salinity, directional spectral wave energy, precision tidal elevation, and current profiles.
- Subsurface Temperature Recorders (STR): Measure high resolution subsurface water temperature.
- Environmental Acoustic Recorders (EAR): Record ambient subsurface sound.

Detailed in situ oceanographic and water quality surveys are accomplished with the following sampling techniques:

- Shallow water CTD casts (max depth 30 m) conducted from small boats at regularly spaced intervals on the 30 m contour around each island/atoll/shoal with an SBE 19+ and an auxiliary transmissometer (Wetlabs C-Star) and oxygen

sensor (SBE 43). Shallow vertical water profiles can provide insight into local water property variation and water mass interactions.

- Shallow water benthic carbonate chemistry sampling over various calcifying reef habitats. Typically sites are chosen based on various degrees of coral cover and are on or near established benthic REA sites so that the biological data can later be correlated with the carbonate chemistry analyses. Water samples (to be analyzed for dissolved inorganic carbon (DIC) and total alkalinity ( $A_T$ )) and “static” CTD casts are carried out at 2 nearby sites (e.g., within about 50 feet of each other at the same depth range and habitat type) directly above the reef, at one site in the mid depth of the water column and at one site just beneath the surface to yield a crude vertical profile of the seawater carbonate chemistry. One salinity sample is collected at each benthic site to calibrate the CTD.
- Shipboard deepwater CTD casts conducted from the NOAA Ship *Hi’ialakai* with an SBE 911+ and an auxiliary SBE 43 Dissolved Oxygen (DO) sensor and Wetlabs ECO FLNTU combination fluorometer and turbidity sensor. Shipboard CTD casts to 500 m, complemented by water samples collected at 3, 80, 100, 125 and 150 m deep for nutrient (NUT) and chlorophyll (CHL) analysis are conducted along a latitudinal transect of permanent stations. Additionally, water samples subsequently analyzed for seawater carbonate chemistry (dissolved inorganic carbon (DIC) and total alkalinity ( $A_T$ )) are collected at the 3 m bin and at the depth bin closest to approximately 50 m below the mixed layer depth (determined real time from the downward cast of the shipboard CTD), usually the 125 or 150 m bin. One salinity sample is collected during each deepwater CTD cast to calibrate the CTD.
- Surface and subsurface water temperatures, as a function of depth, are continuously recorded during all towed-diver operations, providing a broad and diverse spatial and thermal sampling method. Refer to the Towed-diver Habitat/Fish Survey Team Activity Summary for site and isobath information. This data is part of the tow team Arcview project.
- Shipboard meteorological observations including wind speed and direction, relative humidity, air temperature, and barometric pressure.
- Shipboard oceanographic measurements of sea surface temperature, salinity, and currents using an acoustic Doppler current profiler (ADCP).

## A.2 Rapid Ecological Assessment Methods

*(Fish: Paula Ayotte, Cori Kane, Amanda Meyer, Yumi Yasutake; Corals: Jason Helyer, Stephanie Schopmeyer; Algae: Cristi Richards; Inverts: Molly Timmers; ARMS: Russell Moffitt, Elizabeth Keenan)*

Every effort was made to revisit long-term monitoring sites first established in 2004 (Table A.2.1). At each site visited in 2008 (Table A.2.2.), three 25-m transect lines were

laid out by the fish team, separated from each other by approximately 2–3 m. At most sites, transects were laid out at between 3 and 15 m depth. The fish REA team also conducted additional surveys at randomly selected sites. REA methods for each specific discipline are as follows.

#### *A.2.1 Algae*

##### OBJECTIVES OF STUDY:

- Determine which macroalgal species are present in each island ecosystem and in what quantity;
- Examine how algal diversity and abundance change over time;
- Assess whether changes in algal populations serve as good environmental indicators of reef health;
- Formulate biogeographical hypotheses about algal dispersal and evolution using qualitative and quantitative data from island groups around the Pacific.

The goal of algal surveys is to quantitatively describe the algal community and prepare a comprehensive species list for each site. Working at depths of 3 m to 16 m with teams from other biological disciplines that utilize other existing rapid assessment protocols, a point-intercept method for algal assessment has been created that minimizes the time in the water, yet yields the greatest amount of data possible. A single phycologist (usually teamed up with the macroinvertebrate diver during field surveys) collects data using a point-intercept method and records the macroalgal species, algal functional group, coral species, non-coral invertebrate functional group, or substrate type at 20-cm intervals along two 25-m transect lines on a sheet of waterproof paper. Additionally, a roving-diver swim at the end of the dive that covers a swath on 3 m on either side of the transect line is used to record specimens not observed along the transects themselves. One specimen of each species that cannot be identified in the field will be collected by hand. If samples can be identified in the field, no samples will be collected. Algal species inventories and percent cover will be generated from data collected at each site. A high-resolution digital camera mounted on a 0.18 m<sup>2</sup> photoquadrat frame is also used to create permanent historical records of benthic marine substrates at each site.

Numerous species of algae unknown to science are frequently being described from Pacific Islands. The possibility of describing new species (thus increasing our understanding of biodiversity) is great. Detailed microscopic analysis and the placement of holotype specimens in internationally accepted herbaria are a necessary part of this process. Additionally, an understanding of algal species ranges and genetic similarity across Pacific Islands will enable biogeographic hypotheses to be formulated and provide information for marine dispersal mechanisms useful to biologists in many different disciplines. Ultimately, field-collected algal specimens will be critically analyzed in the laboratory to ensure positive species identification, will be catalogued, and will subsequently be placed in research institutions where they can be accessed by researchers interested in a suite of topics. After identification, provisions are made to ensure appropriate preservation and curation of each algal specimen, providing a historical record that will be available to future researchers.

### A.2.2 Corals

At each site, two 25-m belt transects were laid out. Five 2.5-m segments were surveyed for each transect (beginning at points: 0, 5, 10, 15, and 20 m for a total of 25 m<sup>2</sup> per site). For each segment, all coral colonies whose center fell within 0.5 m of either side of the transect were identified to species and measured for size (maximum diameter and diameter perpendicular to the maximum diameter). In addition, the extent of mortality, both recent and long dead, was estimated for each colony. Observers paid special attention to identifying, as best as possible, the extent of the former live colony. When a coral colony exhibited signs of disease or compromised health, additional information was recorded including type of affliction (bleaching, skeletal growth anomaly, white syndrome, tissue loss other than white syndrome, trematodiasis, necrosis, other, pigmentation responses, algal overgrowth, and predation), severity of the affliction (mild, moderate, marked, severe, acute), as well as photographic documentation and sometimes tissue samples. Tissue samples were catalogued and fixed in buffered zinc-formalin solution for further histopathological analyses.

### A.2.3. Non-coral Invertebrate Surveys

Quantitative counts and percent cover for specific target marine invertebrates are done along two separate 1 X 25 m belt transects at 5-m intervals. Size frequency distribution of urchin species will be recorded for the first 25 individuals of each species. Based on data from previous rapid ecological assessments, a group of target species was chosen for quantitative counts. The species in this list were chosen because they have been shown to be common components of the reef habitats of the central and southern Pacific, and they are species that are generally visible (i.e., non-cryptic) and easily enumerated during the course of a single 50–60 min dive.

These target species are:

#### CNIDARIA

Octocorals – soft corals (*Sinularia*, *Cladiella*, *Lobophyton*, *Sarcophyton* etc)

Zoanthids – rubber corals

Actiniaria – Anemones (*Heteractis*, *Stichodactyla*, *Phymanthus* etc)

#### ECHINODERMS

Echinoids – sea urchins

Holothuroids – sea cucumbers

Asteroids – sea stars

#### MOLLUSCA

Bivalves – spondylid oysters, pearl oysters, tridacnid clams (Giant Clams)

Large Gastropods – *Charonia* (Triton's Trumpet) and *Lambis* sp. (Spider Conch)

Coralliophilidae gastropods

Cephalopods - octopus

#### CRUSTACEA

hermit crabs, lobsters, large crabs

Specific in situ methods for each transect



Conduct enumerations at 5-m intervals along the 1 X 25 m transect line:

- Count all species of urchins. Also record test diameter for the first 25 of all species present
- Presence/Absence (P/A) for octocorals (*Carijoa*, *Sarcophyton*, *Lobophyton*, *Cladiella*), zoanthids, colonial anemones
- Count Cnidarians = Anemones (> 7 cm diameter), sea fans
- Count Holothuroids = all visible species
- Count Asteroids = all visible species
- Count Molluscs = Bivalves ( *Pinctada*, *Tridacna*), large gastropods (*Charonia*, *Lambis*), Coralliophilid gastropods
- Count Crustacea = Large Hermit crabs (e.g.; *Dardanus* sp. and *Aniculus maximus* ), large brachyuran (*Carpilius*, *Etisus*, *Dromia* ) , spiny and slipper lobster, trapezid crabs and small hermit crabs

#### A.2.3.1 Autonomous Reef Monitoring Systems (ARMS)

ARMS were deployed at the forereef habitats and lagoon habitats in the atoll systems. ARMS provide a mechanism to quantify marine invertebrates that are not easily identifiable or accountable on the transect lines. They remain on the benthos for 2 years enabling the recruitment and colonization of lesser known, cryptic marine invertebrates.

#### A.2.4 Fish

The fish team, composed of four divers, conducted belt transect (BLT) surveys at pre-selected sites. Two separate teams, consisting of two divers each, were deployed to conduct the surveys. The first team (fish team 1) accompanied the benthic REA team and surveyed previously visited permanent sites conducting three BLTs at each permanent site. The second team (fish team 2) was deployed on a separate boat and surveyed new, randomly chosen sites. Two BLTs were conducted at each new site, and divers took note of substrate type, percent coral and algal cover, and habitat complexity. Sites were pre-determined from satellite imagery, and fell into three depth categories: shallow (0–6 m), mid (6–18 m), and deep (18–29 m). Surveys were performed using a 25-m line set along a single depth contour. As the line was set, two observers swam along either side of the line identifying, counting, and sizing all fishes > 20 cm in total length (TL) within an area 25 m long and 4 m wide. The divers then returned along their respective sides of the transect line identifying, counting, and sizing all fishes < 20 cm TL in a 2 m wide by 25 m long belt. Compass headings, and depth of transect lines were recorded for each transect.

No collection efforts were made by the fish teams during the survey period.

Table A.2.1 Established CRED and NWHIMNM long-term REA monitoring sites in the NWHI 2002-2006.

												NWHI long-term monitoring sites with Maragos permanent transect markers		
REA sites selected and surveyed for long-term monitoring by fish and benthic teams														
Coordinates listed are from CRED 2003 surveys (except LAY-R11, 2004) or from Maragos/Aeby permanent transects where used														
Transect depths are from CRED 2004 benthic surveys, or from Maragos/Aeby permanent transects; azimuth from 2005 Reserve surveys; NR = no record														
Site #	most recent CRED survey date	Reserve 2005 survey date	Using Maragos Perm. Transect ?	Using Aeby Perm. Transect ?	Degree decimal minutes				Transect depth (ft)	Azimuth*	Degree decimal		Site #	Using Maragos Perm. Transect ?
					Latitude (N)		Longitude (W)				Latitude	Longitude		
					Degrees	minutes	Degrees	minutes						
Necker														
R6	7/14/03	10/4/05	Rrm1		23	34.524	164	42.312	30		23.5754	-164.7052	R6	Rrm1
4	7/14/03	10/4/05			23	34.437	164	42.228	30	120	23.5740	-164.7038	4	
2	7/14/03	10/4/05			23	34.693	164	42.384	34	190	23.5782	-164.7064	2	
FFS														
H6	9/04/06	9/18/05	5P		23	52.812	166	16.392	23-43		23.8802	-166.2732	H6	5P
21	9/04/06	9/18/05		Yes	23	50.822	166	19.630	25	t1,130/t2,270	23.8470	-166.3272	21	
22	7/15/03				23	51.933	166	14.381	NR	NR	23.8659	-166.2554	22	
R46	9/30/06		P3		23	46.158	166	15.696	15-30		23.7693	-166.2616	R46	P3
32	9/30/06	9/17/05			23	48.366	166	13.849	25-30	120	23.8061	-166.2308	32	
33	9/30/06	9/17/05			23	50.142	166	15.952	25	80	23.8357	-166.2659	33	
34	9/05/06	9/19/05			23	37.682	166	8.122	35	40	23.6280	-166.1354	34	
R29	9/05/06	9/19/05			23	40.711	166	8.791	20-25	t1,95/t2,150	23.6785	-166.1465	R29	
12	9/05/06	9/19/05		Yes	23	38.323	166	10.802	30	140	23.6387	-166.1800	12	
R30	9/18/04				23	51.994	166	12.870	5	NR	23.8666	-166.2145	R30	
23	9/16/04	9/17/05			23	51.943	166	14.382	5	200	23.8657	-166.2397	23	
30	9/04/06	9/18/05		Yes	23	50.993	166	17.846	14	320	23.8499	-166.2974	30	

Gardner Pinnacles											Gardner Pinnacles		
R3	9/20/04			24	59.812	167	59.929	54	NR	24.9969	-167.9988	R3	
R6	9/20/04			25	0.028	168	0.068	57	NR	25.0005	-168.0011	R6	
					59.934					24.9989	-167.9998		
R5	9/20/04		Rrm1	24		167	59.988	40-50'				R5	Rrm1
Maro											Maro		
R5	9/09/06			25	22.091	170	30.102	24	NR	25.3682	-170.5017	R5	
R6	9/21/04			25	20.471	170	30.032	38	NR	25.3412	-170.5005	R6	
R8	9/21/04	9/20/05		25	20.053	170	31.514	45	10	25.3342	-170.5252	R8	
R12	9/07/06	9/21/05	Yes	25	28.279	170	38.574	45	40	25.4713	-170.6429	R12	
R9	9/22/04	9/21/05	Yes	25	27.671	170	40.994	60	90	25.4612	-170.6832	R9	
R3	9/07/06	9/21/05		25	25.129	170	40.161	60	t1,80/t2,160	25.4188	-170.6694	R3	
8	9/08/06	9/22/05	Yes	25	25.000	170	35.030	25	t1,225/t2,300	25.4167	-170.5838	8	
6	9/08/06	9/22/05		25	23.892	170	34.439	20	20	25.3982	-170.5740	6	
22	9/08/06	9/22/05	Yes	25	22.720	170	34.044	51	51	25.3787	-170.5674	22	
Laysan											Laysan		
5	9/10/06			25	47.240	171	43.760	NR	NR	25.7873	-171.7293	5	
R12	9/10/06			25	46.657	171	44.833	33-47	NR	25.7776	-171.7472	R12	
R9	9/10/06			25	45.233	171	44.468	26-37	NR	25.7539	-171.7411	R9	
R11	9/24/04			25	45.932	171	44.653	18-46	NR	25.7655	-171.7442	R11	
Lisianski											Lisianski		
10	9/27/06			25	56.460	173	55.338	28-31	NR	25.9410	-173.9223	10	
R10	9/27/06			25	56.675	173	57.212	37-46	NR	25.9446	-173.9535	R10	
R7	9/27/06			25	57.227	173	58.234	34-38	NR	25.9538	-173.9706	R7	
16	9/26/06			25	59.226	173	59.688	40	NR	25.9871	-173.9948	16	
17	9/26/06			25	58.155	173	57.774	33-38	NR	25.9693	-173.9629	17	
R14	9/25/06			26	4.692	173	59.822	48	NR	26.0782	-173.9970	R14	
12	9/25/06			26	3.957	174	0.099	24-28	NR	26.0660	-174.0017	12	
R9	9/25/06			26	2.368	174	0.746	26	NR	26.0395	-174.0124	R9	
18	9/26/06			26	0.253	173	59.659	21-28	NR	26.0042	-173.9943	18	

Pearl & Hermes												Pearl & Hermes		
R39	9/23/06	9/26/06			27	56.437	175	51.704	41-48	50	27.9406	-175.8617	R39	
26	9/27/04	9/26/06	Yes		27	57.468	175	48.125	5	350	27.9578	-175.8021	26	Yes
24	9/23/06	9/26/06			27	55.175	175	51.695	24-34	150	27.9196	-175.8616	24	
R44	9/23/06		Yes		27	54.631	175	54.280	46	NR	27.9105	-175.9047	R44	Yes
R22	9/30/04				27	53.952	175	54.897	11-16	NR	27.8992	-175.9150	R22	
23	7/30/03				27	52.868	175	55.967	NR	NR	27.8811	-175.9328	23	
R26	9/12/06	9/25/05			27	47.154	175	46.819	40	60	27.7859	-175.7803	R26	
R31	9/12/06	9/25/05			27	49.605	175	47.518	34	150	27.8268	-175.7920	R31	
R32	9/12/06	9/25/05	PH7	Yes	27	50.072	175	45.210	3	200	27.8345	-175.7535	R32	PH7
33	9/14/06				27	47.138	175	49.393	40	NR	27.7856	-175.8232	33	
22	9/14/06				27	47.723	175	51.990	6	NR	27.7954	-175.8665	22	
30	9/13/06				27	46.761	175	53.710	9	NR	27.7794	-175.8952	30	
R42	9/13/06	9/24/05			27	45.185	175	56.941	45	340	27.7531	-175.9490	R42	
31	9/13/06	9/24/05		Yes	27	46.532	175	58.401	19	240	27.7755	-175.9734	31	
32	9/14/06	9/24/05		Yes	27	46.351	175	56.370	21	120	27.7725	-175.9395	32	
Midway												Midway		
2	9/15/06	9/27/05			28	11.843	177	20.765	38-43	70	28.1974	-177.3461	2	
H10	10/2/04	9/27/05			28	12.908	177	25.504	40-45	350	28.2151	-177.4251	H10	
R7	9/15/06	9/27/05			28	11.791	177	22.495	46-49	60	28.1965	-177.3749	R7	
3	9/16/06		Rrm7		28	13.068	177	20.639	30		28.2178	-177.3440	3	Rrm7
R15	10/1/04	9/28/05			28	14.223	177	23.687	5-9	80	28.2371	-177.3948	R15	
H11	9/21/06				28	13.065	177	24.196	NR	NR	28.2178	-177.4033	H11	
R3	9/15/06				28	11.420	177	23.972	36-51	NR	28.1903	-177.3995	R3	
R20	9/16/06		17P		28	13.902	177	19.086	5-10		28.2317	-177.3181	R20	17P
R25	9/16/06		19P		28	11.616	177	24.102	5-8		28.1936	-177.4017	R25	19P
H21	9/21/06	9/28/05	Rrm13		28	16.650	177	21.978	8		28.2775	-177.3663	H21	Rrm13
1	9/21/06	9/28/05		Yes	28	16.148	177	23.181	3	350	28.2691	-177.3864	1	
Kure												Kure		
12	9/17/06	9/30/05			28	22.951	178	19.484	31-35	120	28.3826	-178.3253	12	
R33	9/18/06	9/29/05			28	25.006	178	22.706	46-48	200	28.4163	-178.3778	R33	
17	9/18/06	9/30/05		Yes	28	25.912	178	22.003	3	100	28.4319	-178.3667	17	

2	9/17/06	9/29/05		28	27.218	178	20.626	31-50	50	28.4535	-178.3432	2	
18	9/19/06		TBD*	28	25.087	178	20.649	18-24	NR	28.4180	-178.3444	18	TBD*
9	9/19/06			28	24.346	178	20.537	14-18	NR	28.4058	-178.3423	9	
R36	9/18/06	9/29/05		28	25.215	178	22.281	8	190	28.4206	-178.3715	R36	
14	9/17/06	9/30/05	Yes	28	27.209	178	19.716	3	70	28.4535	-178.3286	14	
R35	9/19/06			28	23.581	178	20.958	11-16	NR	28.3925	-178.3495	R35	

Table A.2.2.--Long-term monitoring sites visited during HI-08-09.

Island	Site	Habitat	Quadrant 1	Quadrant 2	Depth (m)	Latitude	Longitude	Date visited
French Frigate Shoals	FFS-H6	Forereef	N	NW	8.5–10.6	23°52.806 N	166°16.384 W	15 Sept 2008
	FFS-12	Lagoon	S	SE	9.4–10.1	23°38.301 N	166°10.803 W	16 Sept 2008
	FFS-21	Lagoon	N	NW	7.0–10.5	23°50.809 N	166°19.612 W	15 Sept 2008
	FFS-22	Lagoon	N	NW	2.7–3.4	23°51.954 N	166°15.324 W	8 Oct 2008
	FFS-25	Forereef	E	SE	9.2–11.0	23°42.249 N	166°03.648 W	16 Sept 2008
	FFS-29	Forereef	N	NE	8.8–10.1	23°50.613 N	166°08.204 W	8 Oct 2008
	FFS-R29	Lagoon	S	SE	9.0–15.0	23°40.697 N	166°08.799 W	16 Sept 2008
	FFS-30	Lagoon	N	NW	8.5–10.5	23°50.986 N	166°17.868 W	15 Sept 2008
	FFS-R30	Backreef	N	NW	0.6–0.9	23°51.522 N	166°12.354 W	9 Oct 2008
	FFS-32	Lagoon	N	NW	4.9–9.8	23°48.366 N	166°13.838 W	9 Oct 2008
	FFS-33	Lagoon	N	NW	8.8–11.0	23°50.188 N	166°16.010 W	8 Oct 2008
	FFS-34	Forereef	S	SE	9.5–10.0	23°37.675 N	166°08.123 W	14 Sept 2008
	FFS-35	Lagoon	N	NW	13.0–16.2	23°47.437 N	166°13.921 W	7 Oct 2008
	FFS-R46	Lagoon	W	NW	6.4–10.7	23°46.157 N	166°15.704 W	9 Oct 2008
Maro Reef	MAR-R1	Forereef	W	NW	8.5–10.5	25°27.678 N	170°40.524 W	18 Sept 2008
	MAR-R3	Forereef	W	NW	12.2–17.4	25°25.131 N	170°40.167 W	18 Sept 2008
	MAR-08	Forereef	W	NW	2.7–7.0	25°24.996 N	170°35.025 W	19 Sept 2008
	MAR-R12	Forereef	N	NW	13.5–15.5	25°28.267 N	170°38.576 W	18 Sept 2008
	MAR-22	Forereef	S	SE	14.3–18	25°22.726 N	170°34.042 W	19 Sept 2008
	MAR-32	Forereef	S	SE	11.0–14.9	25°21.245 N	170°32.358 W	19 Sept 2008
Laysa	LAY-05	Forereef	N	NE	5.8–11.2	25°47.244 N	171°43.743 W	20 Sept 2008
	LAY-R9	Forereef	S	SW	6.0–13.7	25°45.238 N	171°44.463 W	20 Sept 2008
	LAY-R12	Forereef	W	NW	7.0–13.6	25°46.662 N	171°44.833 W	20 Sept 2008
Lisianski	LIS-R7	Forereef	S	SW	9.7–14.0	25°57.237 N	173°58.228 W	5 Oct 2008
	LIS-10	Forereef	S	SE	8.5–11.3	25°56.460 N	173°55.344 W	5 Oct 2008
	LIS-R10	Forereef	S	SW	10.0–14.6	25°56.671 N	173°57.210 W	5 Oct 2008
	LIS-12	Forereef	N	NW	7.0–8.2	26°03.954 N	174°00.102 W	4 Oct 2008
	LIS-R14	Forereef	N	NW	13.0–14.9	26°04.702 N	173°59.821 W	4 Oct 2008
	LIS-18	Forereef	W	NW	6.4–8.8	26°00.257 N	173°59.642 W	4 Oct 2008
Pearl and Hermes Atoll	PHR-22	Backreef	S	SW	1.0–1.5	27°47.715 N	175°51.997 W	2 Oct 2008
	PHR-23	Backreef	W	NW	5.2–6.4	27°52.868 N	175°55.967 W	3 Oct 2008
	PHR-24	Backreef	N	NW	4.5–6.4	27°55.180 N	175°51.688 W	23 Sept 2008
	PHR-26	Backreef	N	NE	1.5–2.1	27°57.479 N	175°48.131 W	3 Oct 2008
	PHR-R26	Forereef	S	SE	12.0–14.6	27°47.143 N	175°46.825 W	24 Sept 2008
	PHR-30	Backreef	S	SW	2.0–3.0	27°46.722 N	175°53.705 W	2 Oct 2008
	PHR-31	Lagoon	W	SW	6.4–9.1	27°46.532 N	175°58.401 W	22 Sept 2008
	PHR-R31	Lagoon	E	SE	10.7–16.0	27°49.586 N	175°47.484 W	24 Sept 2008
	PHR-32	Lagoon	S	SW	4.8–6.7	27°46.346 N	175°56.376 W	2 Oct 2008
	PHR-R32	Backreef	E	SE	0.9–1.2	27°50.072 N	175°45.210 W	24 Sept 2008

Island	Site	Habitat	Quadrant 1	Quadrant 2	Depth (m)	Latitude	Longitude	Date visited
	PHR-33	Forereef	S	SE	10.6–12.7	27°47.128 N	175°49.425 W	2 Oct 2008
	PHR-34	Forereef	S	SW	10.7–18.6	27°45.353 N	175°57.707 W	22 Sept 2008
	PHR-R39	Forereef	N	NW	13.3–14.8	27°56.446 N	175°51.705 W	23 Sept 2008
	PHR-R42	Forereef	S	SW	11.3–15.5	27°45.188 N	175°56.926 W	22 Sept 2008
	PHR-R44	Forereef	N	NW	11.0–14.0	27°54.627 N	175°54.276 W	23 Sept 2008
Midway	MID-01	Backreef	N	NW	0.2–1.2	28°16.155 N	177°23.168 W	26 Sept 2008
	MID-02	Forereef	S	SE	12.0–13.5	28°11.840 N	177°20.746 W	28 Sept 2008
	MID-03	Lagoon	S	SE	4.6–9.1	28°13.074 N	177°20.644 W	28 Sept 2008
	MID-R3	Forereef	S	SW	14.0–17.6	28°11.415 N	177°23.993 W	25 Sept 2008
	MID-R7	Forereef	S	SW	13.0–14.8	28°11.782 N	177°22.501 W	25 Sept 2008
	MID-H10	Forereef	W	SW	7.6–11.3	28°12.908 N	177°25.504 W	25 Sept 2008
	MID-H11	Lagoon	W	SW	3.0–5.5	28°13.060 N	177°24.193 W	26 Sept 2008
	MID-R20	Backreef	E	SE	0.9–2.0	28°13.890 N	177°19.091 W	28 Sept 2008
	MID-H21	Backreef	N	NW	0.9–1.2	28°13.060 N	177°24.193 W	26 Sept 2008
Kure	KUR-02	Forereef	N	NW	12.0–13.0	28°27.218 N	178°20.641 W	30 Sept 2008
	KUR-09	Lagoon	S	SW	3.4–6.7	28°24.352 N	178°20.536 W	1 Oct 2008
	KUR-12	Forereef	S	SE	9.0–12.5	28°22.940 N	178°19.474 W	30 Sept 2008
	KUR-14	Backreef	N	NW	0.9–1.5	28°27.209 N	178°19.716 W	1 Oct 2008
	KUR-17	Backreef	W	NW	0.9–3.6	28°25.913 N	178°22.004 W	1 Oct 2008
	KUR-18	Lagoon	W	NW	3.7–8.8	28°25.120 N	178°20.675 W	29 Sept 2008
	KUR-R33	Forereef	W	SW	13.6–15.9	28°25.013 N	178°22.709 W	29 Sept 2008
	KUR-R35	Backreef	S	SW	3.6–4.5	28°23.588 N	178°20.960 W	30 Sept 2008
	KUR-R36	Backreef	W	NW	1.8–3.9	28°25.221 N	178°22.285 W	29 Sept 2008

### A.3. Towed-diver Survey Methods

*(Jacob Asher, Edmund Coccagna, Kevin Lino, Bonie DeJoseph, Benjamin Richards)*

Shallow water habitats around each island, bank, or reef were surveyed using pairs of divers towed 60 m behind a 19-ft SAFE Boat survey launch. In each towed-diver buddy team, one diver is tasked with quantifying the benthos while the other quantifies fish populations. Each towed-diver survey lasts 50 min, broken into ten 5-min segments, and covers approximately 2 km. A Global Positioning System (GPS) track of the survey launch track is recorded at 5-sec intervals using a Garmin GPS76Map GPS unit. A custom algorithm is used to calculate the track of the divers based on the track, speed, and course of the boat and depth of the diver. Each towboard is equipped with a precision temperature and depth recorder (Seabird SBE39) recording at 5-sec intervals. At the end of each day data are downloaded, processed and presented in ArcGIS and can be displayed in conjunction with IKONOS satellite imagery, NOAA chart data and/or other spatial data layers.

#### *A.3.1. Benthic Towed-diver Methods*

The benthic towboard is equipped with a downward high resolution digital still camera with dual strobes. The downward-looking camera is maintained 1–2 m off the bottom and is programmed to photograph benthic substrate every 15 sec, creating a permanent visual record to evaluate and track potential changes in the benthos between subsequent cruises. The diver on the benthic towboard also observes and records habitat composition (habitat complexity, prevalent habitats and substrate types, hard coral, stressed hard, soft coral, macroalgae, coralline algae, sand and rubble), tallies conspicuous macroinvertebrates (crown-of-thorns starfish [COTS]), boring and free sea urchins, sea cucumbers, and giant clams) along a 10-m swath in 10 × 5-min time segments. Additional fields, including prevalent coral and algae genera (when applicable/time permitting) are also tracked. At the end of each day, the data are transcribed from field data sheets into a centralized MS Access database.

#### *A.3.2. Fish Towed-diver Methods*

The fish towboard is equipped with a forward-looking digital video camera which creates a visual archive of the survey track and can be used to evaluate stochastic changes in the reef environment, particularly following episodic events such as coral bleaching and vessel grounding. The diver on the fish towboard records, to the lowest possible taxon, all fish greater than 50 cm total length (TL) along a 10-m swath in each time segment. Fish are recorded in terms of species and length in centimeters. Species of particular concern observed outside the survey swath are classified as presence/absence data and are recorded separately from the quantitative swath data. At the end of each day, the data are transcribed from field data sheets into a centralized MS Access database. Biomass values are calculated using species specific length-weight parameters and are normalized by area (i.e., kg/100 m<sup>2</sup>).

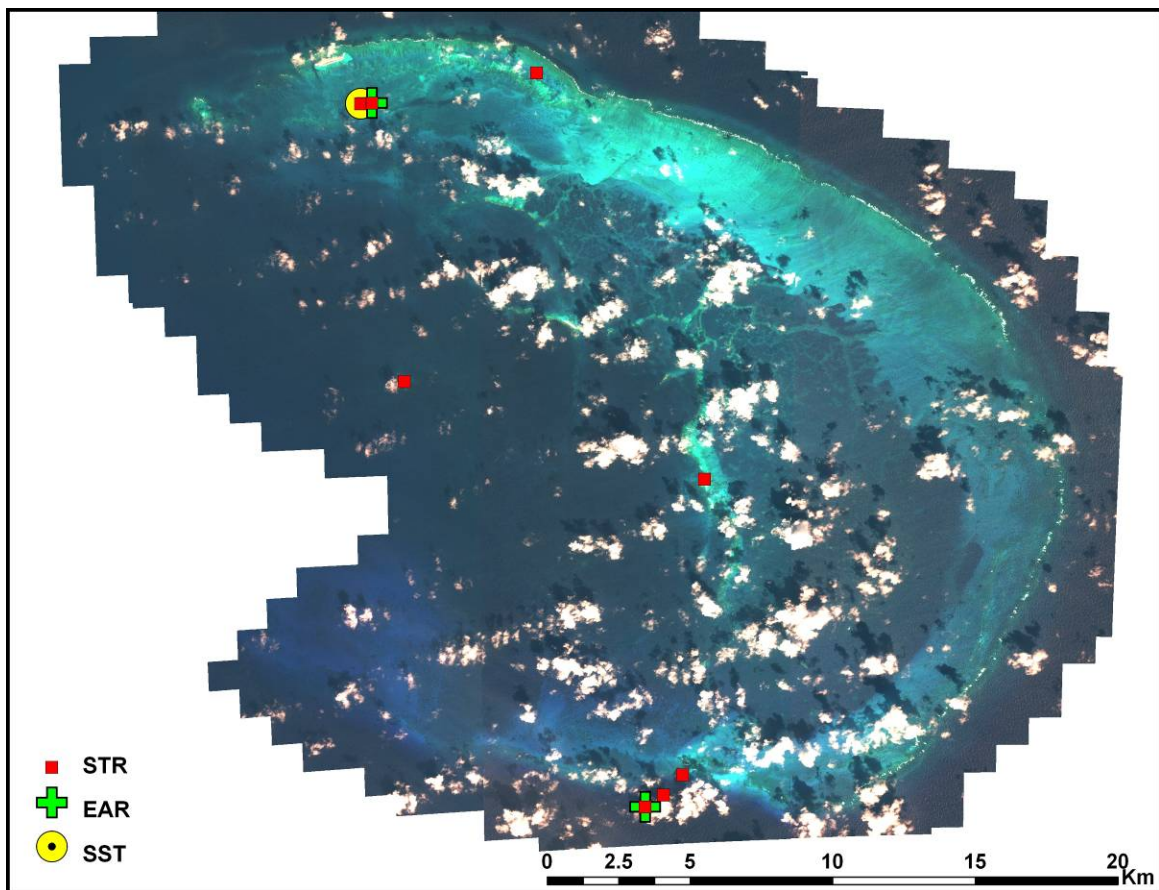


## Appendix B: French Frigate Shoals

### B.1. Oceanography and Water Quality

Moorings (Fig. B.1.1., Table B.1.1.)

Eight subsurface temperature recorders (STRs) were recovered and deployed at French Frigate Shoals during HI0809. A Coral Reef Early Warning System (CREWS) buoy anchor was intended to be removed but was never located; the buoy had previously broken free. A sea surface temperature (SST) buoy with an STR on its anchor was placed at the location that the CREWS buoy had been prior to breaking free. One ecological acoustic recorder (EAR) was moved from just south of Tern Island to La Perouse and one EAR at Rapture Reef in the south was recovered and replaced.



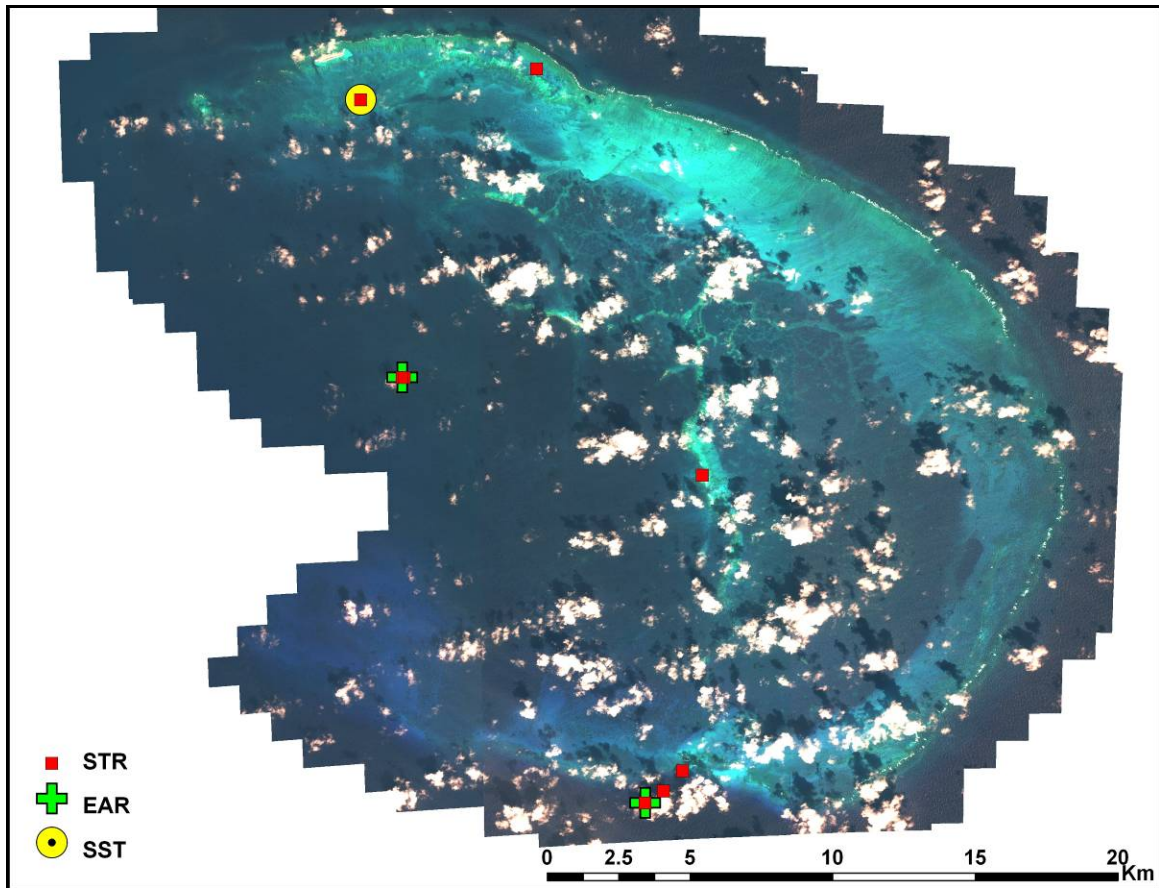


Figure B.1.1.--Moored Oceanographic instrumentation map for French Frigate Shoals. Instruments recovered (top) and instruments deployed (bottom).

Table B.1.1. Moored Oceanographic instrumentation table for French Frigate Shoals.

Instrument	Action	Serial number	Latitude	Longitude	Action Date	Depth (m)
EAR	Deployment	6	23.63507	-	15-Sep-08	23.77
STR	Deployment	3939038-3040	23.63507	-	15-Sep-08	23.77
EAR	Retrieval	9300237-05	23.63507	-	15-Sep-08	23.77
STR	Retrieval	3939038-1871	23.63507	-	15-Sep-08	23.77
STR	Deployment	3939038-3010	23.63880	-	15-Sep-08	10.36
STR	Retrieval	3936839-1670	23.63880	-	15-Sep-08	10.36
STR	Deployment	3939038-3011	23.64515	-	15-Sep-08	1.83
STR	Retrieval	3939038-3004	23.64515	-	15-Sep-08	1.83
SST	Deployment	10017320	23.85623	-	15-Sep-08	7.62
STR	Deployment	3939038-1853	23.85623	-	15-Sep-08	7.62
STR	Retrieval	3939038-1868	23.85623	-	15-Sep-08	7.62

Instrument	Action	Serial number	Latitude	Longitude	Action Date	Depth (m)
SST	Other	10018213	23.85623	- 166.27510	15-Sep-08	0.00
EAR	Retrieval	24	23.63507	- 166.18554	15-Sep-08	0.00
STR	Retrieval	3936859- 1671	23.63507	- 166.18554	15-Sep-08	0.00
STR	Deployment	3939038- 3030	23.76895	- 166.26134	15-Sep-08	4.57
STR	Retrieval	3943236- 3244	23.76895	- 166.26134	15-Sep-08	4.57
STR	Deployment	3939038- 1859	23.76887	- 166.26197	15-Sep-08	10.06
EAR	Deployment	30	23.76887	- 166.26197	15-Sep-08	10.06
STR	Deployment	3951023- 4486	23.86607	- 166.21970	16-Sep-08	3.05
STR	Retrieval	3943236- 3084	23.86607	- 166.21970	16-Sep-08	3.05
STR	Deployment	3939038- 3018	23.73812	- 166.16747	8-Oct-08	0.00
STR	Retrieval	3943236- 3086	23.73816	- 166.16683	8-Oct-08	0.00

### Preliminary Mooring Results

Seven of the eight STRs recovered from French Frigate Shoals yielded quality data sets that showed similar time series trends (Fig. B.1.2.). Between September 2006 and September 2008, subsurface water temperatures around French Frigate Shoals fluctuated with seasonal variability typical for these latitudes; lows occurring between January and March ( $\sim 23^{\circ}\text{C}$ ) and highs between August and October ( $\sim 28^{\circ}\text{C}$ ).

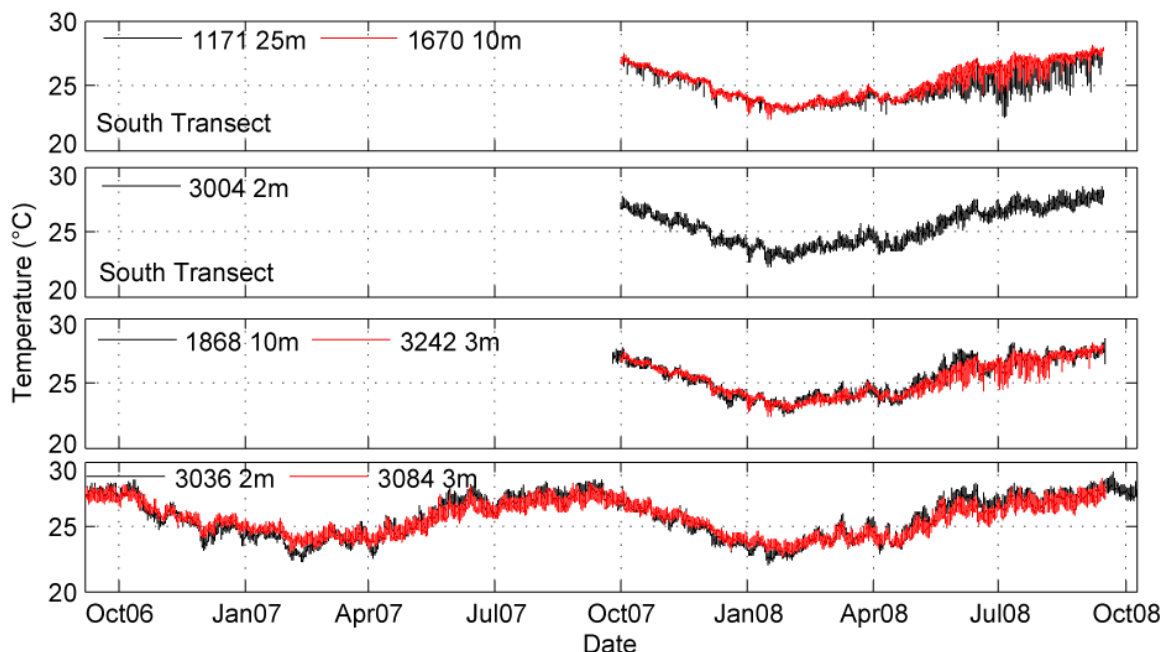


Figure B.1.2.--Temperature data obtained from 7 STR locations at French Frigate Shoals.



## Water Quality:

Twelve shallow-water conductivity, temperature and depth (CTD) casts were conducted at the 30 m bathymetric contour around French Frigate Shoals at approximately 2-nautical mile (nmi) intervals using a Seabird 19+ with additional dissolved oxygen (DO) and transmissometer sensors attached (Fig. B.1.3.). All shallow-water CTD casts were conducted on September 16, 2008. Additionally, 32 “static” (non-profiling mode) shallow-water CTD casts were conducted in conjunction with the benthic seawater carbonate chemistry sampling between October 7 and 9.

Twelve discrete water samples (including one duplicate) were collected concurrently with shallow-water CTD casts at three of the shallow-water CTD sites using a daisy chain of Niskin bottles at 1 m, 10 m, 20 m and 30 m depth bins which will be later analyzed for nutrient, chlorophyll, and carbonate chemistry (dissolved inorganic carbon (DIC) and total alkalinity ( $A_T$ )) content (carbonate chemistry samples were only collected at the 1-m and 10-m bins). Nutrient, chlorophyll, and carbonate chemistry samples were processed and stored according to protocol and will be sent out for analysis following the cruise. In addition to the standard water sampling that accompanies some of the shallow-water CTD sites, benthic seawater carbonate chemistry samples were collected at eight sites around French Frigate Shoals over various benthic habitat types (primarily coral cover). Each of the benthic sites yielded four carbonate chemistry water samples, two from the bottom, one from the mid depth of the water column and one from the just beneath the surface. All benthic carbonate chemistry data will be processed following the cruise.

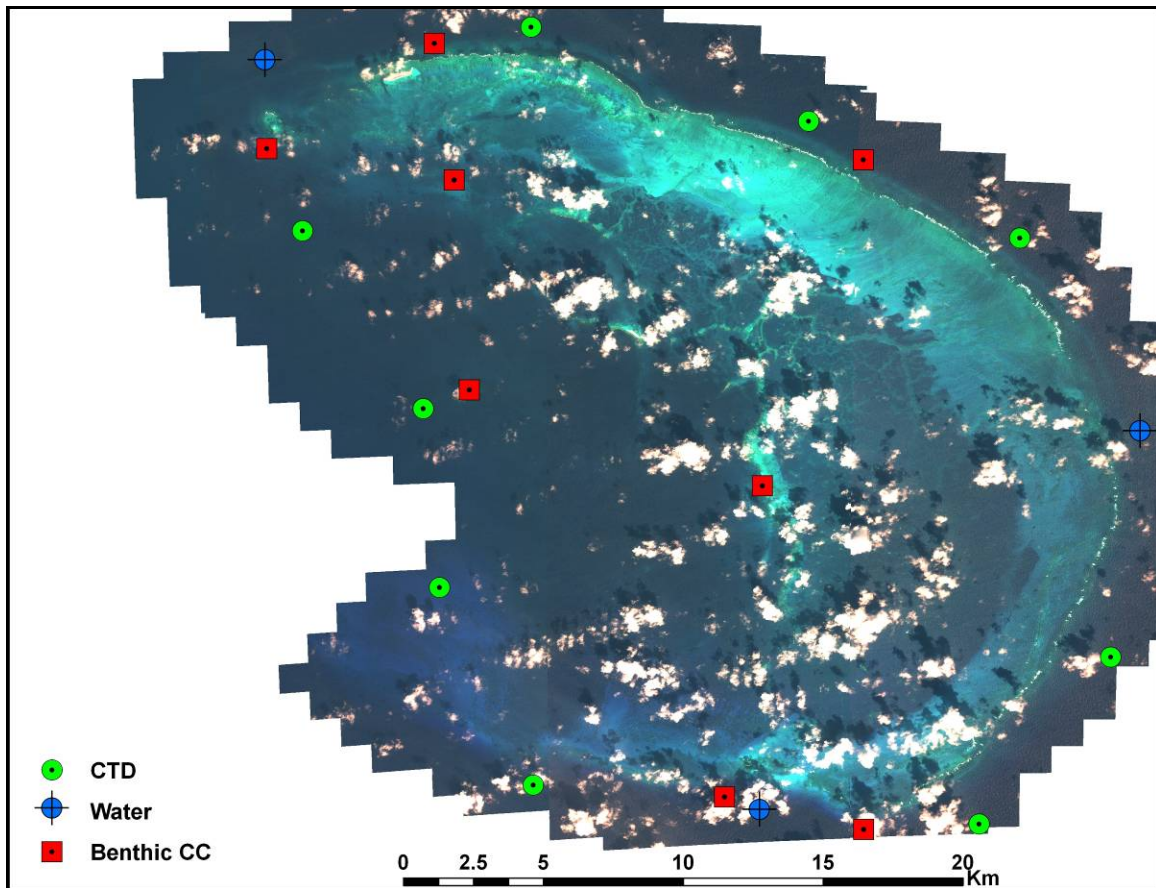


Figure B.1.3.--Shallow-water CTD and water sampling locations around French Frigate Shoals Atoll.

One permanent shipboard CTD site near French Frigate Shoals was sampled, and two sites located 25 km due east and west of the center of the lagoon were sampled as part of a carbonate chemistry transect (Fig. B.1.4.). Each of these casts included a CTD profile to 500 m deep, water samples that will be analyzed for chlorophyll and nutrients at the 3, 80, 100, 125 and 150 m bins, and water samples that will be analyzed for carbonate chemistry (DIC and  $A_T$ ) at the 3 m and 125 m depth bins. The water samples were processed and stored according to protocol and will be sent out for analysis following the cruise.

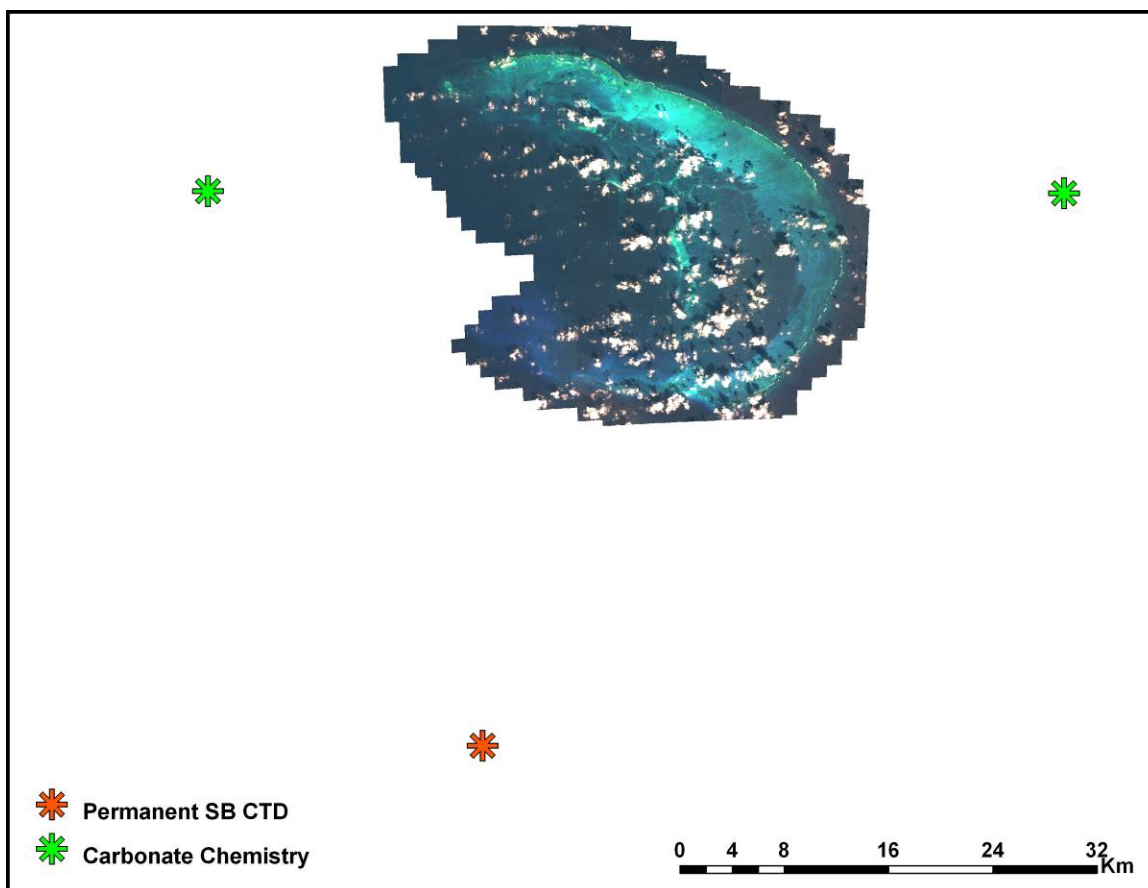


Figure B.1.4.--Permanent shipboard CTD and carbonate chemistry transect locations near French Frigate Shoals.

## B.2. Rapid Ecological Assessment (REA) Site Descriptions

Fourteen REA (Rapid Ecological Assessment) sites were visited by a team of up to eight scientists around French Frigate Shoals between September 14 and 16 and October 7 and 9, 2008. In addition, 19 independent fish surveys were conducted. The site locations can be seen in Figure 1, and the survey dates and efforts can be seen in Table 1. Site descriptions are included for the following discipline communities: coral, coral and coralline disease, macroinvertebrates, algae, and fish.

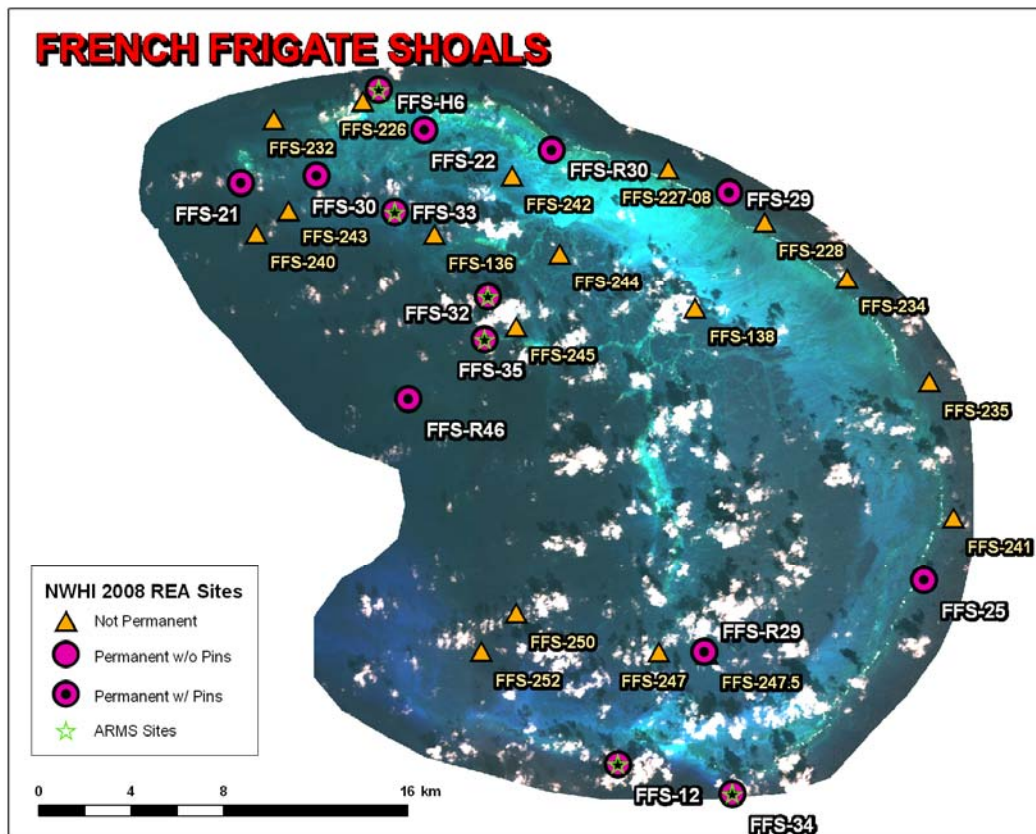


Figure 1.--Map of REA sites at French Frigate Shoals.

Table 1. French Frigate Shoals 2008 REA site survey dates, teams present and additional comments (see also TableA.2.2).

Site Id	Date	Teams Present	Comments
FFS-34	9/14/08	Fish, Coral, Disease, Algae, Invertebrate	ARMS
FFS-H6	9/15/08	Fish, Coral, Disease, Algae, Invertebrate	ARMS
FFS-21	9/15/08	Fish, Coral, Disease, Algae, Invertebrate	
FFS-30	9/15/08	Fish, Coral, Disease, Algae, Invertebrate	
FFS-R29	9/16/08	Fish, Coral, Disease, Algae, Invertebrate	
FFS-12	9/16/08	Fish, Coral, Disease, Algae, Invertebrate	ARMS
FFS-25	9/16/08	Fish, Coral, Disease, Algae, Invertebrate	Permanent transect installed
FFS-35	10/7/08	Fish, Coral, Disease, Algae, Invertebrate	ARMS and Permanent transect installed
FFS-29	10/8/08	Fish, Coral, Disease, Algae, Invertebrate	Permanent transect installed
FFS-33	10/8/08	Fish, Coral, Disease, Algae, Invertebrate	ARMS
FFS-22	10/8/08	Fish, Coral, Disease, Algae, Invertebrate	Permanent transect installed
FFS-32	10/9/08	Fish, Coral, Disease, Algae, Invertebrate	ARMS installed
FFS-R30	10/9/08	Fish, Coral, Disease, Algae, Invertebrate	Permanent transect installed

Site Id	Date	Teams Present	Comments
FFS-R46	10/9/08	Fish, Coral, Disease, Algae, Invertebrate	
FFS-232	9/15/2008	Fish	New site – Forereef
FFS-248 (247.5)	9/16/2008	Fish	New site – Lagoon
FFS-250	9/16/2008	Fish	New site – Lagoon
FFS-247	9/16/2008	Fish	New site – Lagoon
FFS-245	10/7/2008	Fish	New site – Lagoon
FFS-252	10/7/2008	Fish	New site – Lagoon
FFS-241	10/8/2008	Fish	New site – Forereef
FFS-234	10/8/2008	Fish	New site – Forereef
FFS-235	10/8/2008	Fish	New site – Forereef
FFS-229 (227-08)	10/8/2008	Fish	New site – Forereef
FFS-226	10/8/2008	Fish	New site – Lagoon
FFS-243	10/8/2008	Fish	New site – Lagoon
FFS-228	10/8/2008	Fish	New site – Forereef
FFS-244	10/9/2008	Fish	New site – Lagoon
FFS-138	10/9/2008	Fish	New site – Lagoon
FFS-240	10/9/2008	Fish	New site – Lagoon
FFS-136	10/9/2008	Fish	New site – Lagoon
FFS-242	10/9/2008	Fish	New site – Lagoon

## Site Descriptions:

September 14, 2008

### FFS-34

*N 23° 37.67502 , W -166 ° 08.12298*

Depth range: 10–12 m

This low relief site found outside the southern edge of the lagoon was characterized by turf-colonized carbonate rubble/sand. The benthic community was dominated by turf algae and crescent shaped epiphytized blades of *Microdictyon setchellianu*. Crustose coralline red algae, *Halimeda discoidea*, and *Lobophora variegata* were also prevalent. Additionally, a species of *Neomeris* was encountered during the random swim. Coral cover was low (3.6%) consisting mostly of *Pocillopora meandrina* and *Porites lobata*. Ten anthozoan species (nine scleractinia and one zoanthid) were seen within the survey area. One case of tissue loss was noted on a colony of *Porites lobata* as well as a hyperpigmentation response in a colony of *Pocillopora eydouxi*. The boring urchins, *Echinostrephus aciculatus* and *Echinometra mathaei*, dominated the macroinvertebrate community. Several large *Echinothrix sp.* were present and *Calcinus* hermit crabs and *Trapezid* crabs were common. The alien hydroid, *Pennaria disticha*, was observed. A parasitic snail, *Thyca crystalline*, was found on a *Linckia multifora*. Few fish greater than 20 cm were observed. The fish population consisted predominantly of juvenile wrasses; overall species diversity was low.

September 15, 2008

**FFS-H6**

N 23° 52.807467 , W -166 ° 16.3878558

Depth range: 11–13 m

This site, found north of Tern Island, was dominated by turf-colonized pavement with *Halimeda velasquezii*, *Microdictyon setchellianum*, *Halimeda discoidea* and *Lobophora variegata*. Coral cover was moderately high (36.4%) dominated by encrusting *Porites lobata* colonies with young *Acropora cytheria* colonies scattered about. Fourteen anthozoan species (13 scleractinia and 1 zoanthid) were seen within the survey area. Pale colonies of *Montipora patula* and *Montipora capitata* were noted. The echinoids, *Echinostrephus* and *Echinometra*, dominated the macroinvertebrate composition. Larger fish seemed to be in the grooves and off transect. Species not recorded in the counts but observed nearby included *Caranx melampygus* in the 80–100 cm range, *Monotaxis grandoculis* in the 40–50 cm range, and *Caranx ignobilis* in the 110–140 cm range.

**FFS-21**

N 23° 50.8130196 , W -166 ° 19.618401

Depth range: 10–12 m

This site, found in the vicinity of Shark Island, was characterized by high coral cover (60%) composed of large colonies of *Acropora cytherea* and encrusting *Porites lobata*. Ten anthozoan species (nine scleractinia and one zoanthid) were seen within the survey area. Skeletal growth anomalies in *Acropora cytherea* were noted although none were enumerated on the transect. The algal community was dominated by turf-colonized pavement, with *Halimeda velasquezii*, crustose coralline red algae, *Halimeda discoidea*, and *Lobophora variegata*. *Caulerpa webbiana* was found during the roving diver survey. Overall, macroinvertebrates were low. *Echinostrephus* was the dominant macroinvertebrate followed by *Echinometra*. *Acanthurus nigrofuscus* and *Ctenochaetus strigosus* dominated the fish community. Additionally, a large school (~ 100) of *Acanthurus triostegus* was seen off transect.

**FFS-30**

N 23° 50.973 , W -166 ° 17.83602

Depth range: 6–9 m

This high relief lagoon habitat had moderately high (24.8%) high coral cover composed of mostly encrusting *Porites lobata* colonies. Ten anthozoan species (nine scleractinia and one zoanthid) were seen within the survey area. A low level of mild bleaching was noted in several colonies including *Montipora patula* and *Montipora capitata*. Turf algae, *Halimeda velasquezii*, crustose coralline red algae, *Microdictyon setchellianum*, *Halimeda discoidea* and *Lobophora variegata* were common. *Haloplegma duperreryi*, *Caulerpa taxifolia*, a species of *Chrysomenia*, *Laurencia majuscula*, and *Jania* were found during the random swim. Overall, the site had good fish species diversity. Large *Oplegnathus* spp. was observed in a cave along with *C. melampygus*, and numerous large *Myrpristis*.

**FFS-232**

N 23 ° 52.157 W 166 ° 18.850

Depth: 16 meters

This site is located at the northwestern forereef of French Frigate shoals. It was established by the REA fish team as a new sampling location in the moderate forereef stratum. The area is characterized by spur-and-groove patches of predominantly *Acropora* and *Porites* corals, with hard pavement. Coral complexity/rugosity was moderate with medium to high live coral cover with moderate amounts of turf algae and halimeda. With the exception of *Echinostrephus aciculatus* and vermitid snails, the



macroinvertebrate community was low. Large schools of *Priacanthus meeki* were just off transect. Large *Lutjanus kasmira* were relatively abundant. Large trevally (*Caranx ignobilis*) and Morwong were recorded off transect as well. The most abundant groups of fishes on transect included *Ctenochaetus strigosus*, *L. kasmira* and *Acanthurus nigrofuscus*.

September 16, 2008

#### **FFS-R29**

*N 23° 40.71102 , W -166 ° 08.784*

Depth range: 8–11 m

This lagoon patch reef site, at the base of a rubble slope and sand patch, had moderate coral cover (22.4%). *Pocillopora damicornis* and Porites species (*lobata*, *evermanni*, and *compressa*) dominated with numerous small colonies of *Cyphastrea ocelina* also noted. Twelve anthozoan species (11 scleractinia and 1 zoanthid) were seen within the survey area. Low levels of bleaching were recorded in a number of colonies including *Monitpora patula* and *Pocillopora damicornis*. The algal community was dominated by turf algae colonizing coral skeletons and *Halimeda discoidia*. *H. velasquezii*, crustose coralline red algae, and *Lobophora variegata* were also prevalent. A species of *Jania*, *Microdictyon setchellianum*, *Gibsmithia hawaiiensis*, *Dictyosphaeria versluysii*, and *D. cavernosa* were found during the roving diver survey. The macroinvertebrate community was moderate. The marine invertebrates commonly noted at the site were the bivalves, *Arcas ventricosa*, *Calcinus* hermit crabs, and the poriferan, *Stylinis* sp. The alien hydroid, *Pennaria disticha*, was observed growing on the transect stakes. There was good diversity in small species of fish, with an abundance of juvenile *Scarus/Chlorurus* spp. Large *Caranx melampygus*, *Aprion virescens*, and one *Carcharhinus amblyrhynchos* were seen off transect. One adult *Chaetodon trifascialis* was observed, although no *Acropora* was seen nearby.

#### **FFS-12**

*N 23° 38.301 , W -166 ° 10.803*

Depth range: 10–12 m

This site was dominated by large *Acropora cytherea* (some over 2 m in diameter) and extremely high coral cover (81.6%). Tags marking diseased colonies were found, although tags have been encrusted by coral. No skeletal growth anomalies or white syndrome were observed within the transect although several cases of each were noted in the general area. Skeletal growth anomalies although a number were seen along the transect, especially near the beginning of the second transect. Predation (from COTs) was observed in one colony of *Acropora cytherea*. Turf and crustose coralline red algae on dead coral skeletons, combined with *Lobophora variegata* were the only algae recorded within the LPI survey. During the roving diver survey, *Haloplegma duperreyi*, *Neomeris* sp., *Halimeda discoidea*, and *Dictyosphaeria versluysii* were also documented. Macroinvertebrates were virtually devoid of this site. Two *Acanthaster planci* were observed. Overall, a diverse fish community was present at this site. A large school of approximately 200 *Lutjanus kasmira*, ranging from 15 to 20 cm, a school of approximately 60 *Parupeneus vanicolensis*, all approximately 17–20 cm, and a school of 10 *Monotaxis grandoculis*, ranging from 70 to 90 cm in total length, were seen. Off transect, five *Caranx ignobilis*, the largest being approximately 150 cm and the rest being 90–130 cm in total length, and *Triaenodon obesus* were seen.

**FFS-25**

N 23° 42.249 , W -166 ° 03.648

Depth range: 11–13 m

This low relief eastern forereef site was last surveyed in 2002. It was dominated by turf-colonized rubble and highly grazed and epiphytized *Microdictyon setchellianum*. *Lobophora variegata*, crustose coralline red algae, *Halimeda velasquezii*, *H. discoidea*, and a species of *Neomeris* were noted as well as a species of *Asparagopsis* and *Jania* during the roving diver survey. The moderate coral cover (20%) consisted of mostly *Porites lobata* and *Pocillopora meandrina*. Eleven anthozoan species (10 scleractinia and 1 zoanthid) were seen within the survey area. Fourteen cases of predation on *Pocillopora meandrina* and one case on *Porites lobata* were noted. Several large COTs were seen in the area and predation scars appeared to be recent. The sea urchins, *Echinostrephus aciculatus* and *Echinometra mathaei*, were prevalent. The random coral outcrops were heavily populated with small fish species, *Calcinus* hermit crabs, and *Trapezid* crabs. Numerous *Aprion virescens* were seen in the area along with a couple of *Caranx melampygus*, *C. ignobilis*, *Triaenodon obesus*, and *Carcharhinus amblyrhynchos*.

**FFS-247**

N 23 ° 40.680 W 166 ° 09.840

Depth: 11 m

This site was located in the southern lagoon of French Frigate Shoals. It was established by the REA fish team as a new sampling location in the moderate lagoon stratum. Coral cover here was moderate (~ 40%) and included *Porites lobata*, *P. compressa*, with a smaller number of *Pocillopora damicornis* and *Pavona duerdeni* corals. Complexity was moderate. Dead, sand-covered coral, a red algal overgrowth, black and orange sponges, and rock-boring clams characterized the benthos. Parrotfish were by far the most abundant fish at this site, including *Chlorurus sordidus*, *C. perspicillatus*, *Scarus dubius*, and *S. psitticus*. Two large *Caranx ignobilis* zoomed through the transect, while the slingjaw wrasse *Epibulus insidiator* hid shyly off transect.

**FFS-248**

N 23 ° 40.641 W 166 ° 08.713

Depth: 8 m

This site was located in the southern lagoon of French Frigate Shoals. It was established by the REA fish team as a new sampling location in the moderate lagoon stratum. At this murky patch reef coral cover was moderate (~ 60%) with low to moderate complexity. *Porites lobata* and *P. compressa* were the dominant corals; a large outcropping of *Pavona duerdeni* was also present. The fish assemblage at this site was unremarkable. No large fish were recorded on transect, although a single *Caranx ignobilis* made an appearance after the counts were completed. Moderate sized fish were more commonly seen, including *Chlorurus perspicillatus*, *Naso unicornis*, *Acanthurus blochii* and *A. dussumieri*.

**FFS-250**

N 23 ° 41.515 W 166 ° 13.178

Depth: 17 m

This site was located at the southeastern lagoon of French Frigate Shoals. It was established by the REA fish team as a new sampling location in the lagoon deep stratum. The area is characterized by large patches of corals amidst mostly sandy bottom. Coral patches were large and complex. Coral complexity/rugosity was moderate with high live coral cover, dominated mostly by *Porites* with a few exceptionally large *Acropora* heads. The site contained few *Pocillopora* colonies, but most were bleached. The algae *Caulerpa taxifolia* was relatively abundant throughout the site. The most abundant groups of fishes on transect included 2 parrotfishes, *Chlorurus perspicillatus* and *Chlorurus sordidus*, as

well as the surgeonfish *Ctenochaetus strigosus* and the angelfish *Centropyge potteri*. Off transect, sightings included many *Aprion virescens* and large *Lutjanus kasmira*. Upon ascent, a large grey reef shark and another large ulua curiously approached.

October 7, 2008

**FFS-35**

N 23° 47.437 W 166° 13.921

Depth: 12 m

This site was located in the lagoon nearly due east of La Perouse. There was moderately high percent live coral cover (52.8%), heavily dominated by encrusting *Porites compressa* and highly fissioned *P. lobata*. Numerous cases of compromised health states were observed in the *Porites* genus. The algal community was dominated by turf algae and two species of *Halimeda*, *H. velasquezii* and *H. opunita*, both of which were highly colonized with turf algae. *Laurencia majuscula*, *Microdictyon setchellianum*, *Lobophora variegata*, *Codium arabicum*, and crustose coralline red algae were also documented during the LPI survey. A species of *Neomeris*, *Halimeda discoidea*, *H. gracilis*, *Gibsmithia hawaiiensis*, and species of *Peyssonnelia* and *Nemastoma* were documented on the Roving Diver survey. Overall, macroinvertebrates were low. The bivalves *Spondylus* and *Arca ventricosa*, were common. The site was relatively low in both diversity and abundance of fish on transect. The most frequently recorded fish included the surgeonfish, *Ctenochaetus strigosus*, and the wrasse, *Thalassoma duperrey*. A few large unicornfish and triggerfish were recorded, but not in any large abundances. No large fishes were observed off transect.

**FFS-252**

N 23° 40.694 W 166° 13.997

Depth: 20 m

This site was located in the southeastern lagoon in deep water. It was established by the REA fish team as a new sampling location in the deep lagoon stratum. The habitat was flat with no spur and grooves; however there was moderate to high complexity. The corals formed a latticework creating lots of crevices and holes for small fish. There were *Acropora* tables, *Porites compressa*, and *P. lobata* at 80% coral cover. There was good species diversity and a high number of *Scarid* spp. that were under 20 cm. Many of the *Ctenochaetus strigosus* has diseased lesions on their skin. There was a 150-cm *Triaenodon obesus*, and 12 *Aprion virescens* from 30 to 100 cm of transect.

**FFS-245**

N 23° 47.692 W 166° 13.176

Depth: 12 m

This site was located in the lagoon of French Frigate Shoals. It was established by the REA fish team as a new sampling location in the moderate lagoon stratum. This small patch reef appeared as an isolated oasis in the midst of a flat, sandy desert of rubble and *Halimeda*. As this patch reef was the only substrate in the area, only one transect was laid. Coral cover was high, approximately 80% comprised of *Porites compressa*, *P. lobata*, and a single *Acropora* table. Complexity was also high. Fish diversity and abundance were high, with especially high counts of scarids (*Chlorurus sordidus* and *Scarus dubius*) and damsels (*Dascyllus albisella*). Large acanthurids (*Acanthurus dussumieri* and *Naso unicornis*) were also common. Off transect, a large *Caranx ignobilis* and almost a dozen *Aprion virescens* darted.

October 8, 2008

**FFS-29**

*N 23 ° 50.613 W 166 ° 08.204*

Depth: 14 m

This northern forereef site had not been surveyed since 2002. Coral cover, dominated by *Pocillopora*, was moderate (21.6%). However, coral diversity was the highest recorded on this cruise with 19 anthozoan species. The algal community was dominated by *Lobophora variegata* and turf-colonized pavement with a low percent cover of *Halimeda velasquezii*, *Microdictyon setchellianum*, and crustose coralline red algae. *Halimeda discoidea*, a species of *Neomeris*, and a cyanophyte were documented on the Roving Diver survey. The boring urchins, *Echinostrephus aciculatus* and *Echinometra mathaei*, were prevalent. Coral eating snails, *Coralliophilidae*, *Calcinus* hermit crabs, and Trapezid crabs were common in *Pocillopora* heads. The starfish, *Linckia multifora*, was occasional. Fish abundance and diversity was relatively high at this site. Four *Caranx ignobilis* in the 80–90 cm range were among the largest fish recorded on transect, along with one 140-cm *Carcharhinus galapagensis*. One *Triaenodon obesus*, approximately 140 cm, was also seen off transect. *Thalassoma duperrey* was the most abundant fish under 20 cm, along with *Acanthurus nigrofusus*, *Chromis vanderbilti*, *C. hanui*, and *Paracirrhites arcuatus*. A school of approximately 20 *Monotaxis grandoculis* in the 40–60 cm range was also seen off transect.

**FFS-33**

*N 23 ° 50.188 W 166 ° 16.010*

Depth: 10 m

This lagoon site was located nearly halfway between La Perouse and Tern Island. Live coral cover (26.8%), heavily dominated by encrusting and highly fissured *Porites lobata*, was moderate. *P. compressa* and *P. evermanni* were also abundant. Numerous cases of compromised health condition were detected on *P. lobata*, *P. compressa*, and *P. evermanni*, and most *Montipora* species appeared bleached and exhibited partial mortality. The algal community was dominated by *Lobophora variegata* and turf algae with a low percent cover of *Halimeda velasquezii*, *H. gracilis*, *Microdictyon setchellianum*, and crustose coralline red algae. *Halimeda discoidea*, *Dasya iridescens*, *Caulerpella ambigua*, a cyanophyte, a species of *Neomeris*, non-geniculate coralline red algae, *Caulerpa webbiana*, and *Caulerpa taxifolia* were documented on the Roving Diver survey. Overall, macroinvertebrate diversity and abundance were low. The echinoids, *Echinometra* and *Echinostrephus*, were rare. However, fish diversity and abundance at this site was relatively high. Fish less than 20 cm that were most abundant on site include *Ctenochaetus strigosus*, *Thalassoma duperrey*, and juvenile scarids. Of the parrotfish present, the most numerous were *Chlorurus perspicillatus*, *Scarus dubious*, and *C. sordidus*. Fish encountered over 20 cm include *Bodianus bilunulatus*, *Caranx ignobilis*, *C. melampygus*, *Aprion virescens*, *Carangoides orthogrammus*, and *C. perspicillatus*.

**FFS-22**

*N 23 ° 51.954 W 166 ° 15.324*

Depth: 3 m

This site, composed of rubble patches surrounded by sand near both Whale Island and Skate Island, was more of a poorly developed lagoonal patch reef than a backreef site. Coral cover was extremely low (1.6%) and consisted of scattered *Pocillopora* sp., *Pssamacora stellata*, and *Cyphastrea ocellina*. The benthos was dominated by highly epiphytized *Microdictyon setchellianum* and turf algae. There was a relatively low percent cover of *Lobophora variegata*, a species of *Liagora*, crustose coralline red algae, non-geniculate coralline red algae, and *Dictyosphaeria versluysii*. *Halimeda velasquezii*, *Turbinaria*

*ornata*, and a species of *Peyssonnelia* were documented on the Roving Diver survey. Macroinvertebrate diversity and abundance were low. Few echinoids were present. Only the collector urchin, *Tripneustes gratilla*, and the boring urchin, *Echinometra*, were seen but rarely. Coral eating snails were common within the few live and small *Pocillopora* heads. The polychaete, *Loimia medusa*, was common. A color morph of the sea cucumber, *Holothuria hilla*, was observed. Fish diversity and abundance were relatively low at this site. Juvenile fish of the more common reef species, such as *Coris venusta*, *Ctenochaetus strigosus*, *Thalassoma duperrey*, and *Apogon kallopterus*, under 20 cm made up the majority of the population. A school of 6 *Naso unicornis* in the 50-cm range was seen off transect, along with one *Aprion virescens* approximately 75 cm.

#### **FFS-229**

N 23° 51.086 W 166° 09.620

Depth: 5.4 m

This site was located on the northern forereef of French Frigate Shoals. It was established by the REA fish team as a new sampling location in the shallow forereef stratum. This site had flat pavement with very shallow spur-and-groove habitat, with scattered *Pocillopora* and *Acropora* heads, with encrusting *Porites lobata* at 15% coral cover, and shallow sand channels. Turf algae dominated the substrate, and relief was low to moderate. There was a depression and cave near transect A that held some larger fish; 3 *Lutjanus kasmira* at 35 cm, 3 *Naso unicornis* at 40 cm, *N. lituratus*, *Aphareus furca* at 40 and 35 cm, 70 *Acanthurus triostegus* at 12–16 cm, one *Bodianus bilunulatus* at 45 cm, 2 at 30 cm, and 3 at 25 cm.

#### **FFS-235**

N 23° 46.500 W 166° 03.514

Depth: 13.4 m

This site was located on the eastern forereef. It was established by the REA fish team as a new sampling location in the moderate forereef stratum. This low relief, low complexity habitat consisted of flat pavement with scattered *Pocillopora* heads and encrusting *Porites lobata* at 20 to 25% coral cover. Fish abundance on transect was relatively low, with small damsels and chromis being most commonly recorded. Several large fish made it into the counts, including *Aprion virescens*, *Caranx ignobilis*, *Carcharhinus amblyrhynchos* and *C. galapagensis*. Seen off transect were several rarely seen parrotfish, *Scarus rubroviolaceus*, as well as the snapper *Aphareus furca*. Most of the action took place outside the boundaries of the transects, where increasing numbers of reef sharks joined and remained throughout the dive with the divers, who counted up to 22 (mostly Galapagos). At one point, roughly 100 rainbow runners (*Elegatis bipinnulatus*) and a half dozen bluefin trevally (*C. melampygus*) joined the fray, making this dive one of the favorites of the trip.

#### **FFS-228**

N 23° 49.954 W 166° 07.370

Depth: 4 m

This site was located on the northeastern forereef at shallow depth. It was established by the REA fish team as a new sampling location in the shallow forereef stratum. This site had flat pavement with very shallow rolling spur-and-groove habitat, with shallow sand channels, with low to moderate relief. There were scattered *Pocillopora* and *Acropora* heads, with encrusting *Porites lobata* at 25% coral cover. There were cave-like depressions with cracks and ledges, with high relief that held high densities and high fish diversity. The usual gang of parrots and wrasses were counted, and larger fish on transect *Caranx melampygus*, *Carangoides orthogrammus*, *Aphareus furca*, and *Naso unicornis*. Off transect, *Scarus rubroviolaceus*, *Triaenodon obesus*, *C. ignobilis*, and *Carcharhinus amblyrhynchos* cruised by.

**FFS-234**

N 23° 48.743 W 166° 05.446

Depth: 7 m

This site was located on the eastern forereef of French Frigate Shoals. It was established by the REA fish team as a new sampling location in the moderate forereef stratum. The habitat consisted of flat pavement with scattered *Pocillopora* heads and encrusting *Porites lobata* at 10 to 15 % coral cover. The rest of the substrate was rubble covered with turf algae. There was low diversity on the transects with mostly wrasses, making up 6 of the 15 spp. present on the transects. Off transect, there were 30 *Acanthurus triostegus* at 15 cm, 3 *Naso unicornis* at 40 cm, and *Triaenodon obesus* at 4.5 ft, and a grey reef shark at 5 ft.

**FFS-241**

N 23° 43.577 W 166° 02.963

Depth: 21.6 m

This site was located on the eastern forereef. It was established by the REA fish team as a new sampling location in the deep forereef stratum. The habitat was flat rubble with sand patches and dominated by algae. There were scattered *Pocillopora* heads and *Porites lobata* at 5 to 8 % coral cover. There were a few outcroppings where fish aggregated, and fish densities and diversity were higher than on the rest of the transect. The transects were dominated by wrasses (6 spp.), balistids (3 spp.) and acanthurids (3 spp.). Several larger fish species were seen off transect: 7 *Monotaxis grandoculis* at 40–60 cm, a grey reef shark at 6 ft, a Galapagos shark at 7 ft, 100 *Acanthurus olivaceus*, 10 *Caranx melampygus* at 45–65 cm, 12 *Naso hexicanthus* at 45 cm, and 1 *Aphareus furca* at 40 cm.

**FFS-243**

N 23 ° 50.196 W 166 ° 18.502

Depth: 16 m

This site is located in the lagoon of French Frigate Shoals. It was established by the REA fish team as a new sampling location in the moderate lagoon stratum. This site contained large *Acropora* table corals as well as 3 species of *Porites* with approximately 70% live cover. Rugosity of rock substrate was low, but Acroporids provided some relief. The substrate was interspersed with small sandy patches. Algae were relatively abundant at this site, but mostly consisted of Halimeda. Red and green foliose algae were observed in smaller abundances than the Halimeda. Visibility was limited due to fine particles in the water column. Abundance and diversity was moderate with butterflyfish (*Chaetodon trifascialis*, *C. fremblii*, *C. ornatissimus*) and juvenile *Ctenochaetus strigosus* dominating the site. Most fish encountered were captured on the transects, but adult unicornfish, emperors and jobfish were observed off transect as well.

**FFS-226**

N 23 ° 52.540 W 166 ° 16.758

Depth: 4 m

This site is located in the northern forereef of French Frigate Shoals. It was established by the REA fish team as a new sampling location in the shallow forereef stratum. This site was composed of moderate rugosity rock substrate. No bare rock was visible as it was covered equally with zooanthids and coralline algae (approximately 70% zooanthids, 30% coralline algae). Coral cover was low with less than 1% live coral cover, although many species of coral comprised the live cover, including *Pocillopora*, *Porites lobata*, *Montipora* and *Porites pavona*. Halimeda was commonly observed growing on the coralline algae, as well as sparse patches of turf algae. Diversity and abundance of fish was moderate to high, and the majority of fishes observed were large adults. Surgeonfishes were most

abundant, specifically the species *Acanthurus nigrofuscus*, *A. nigroris* and *Ctenochaetus strigosus*. A grey reef shark was observed off transect, as well as one large *Caranx ignobilis*. Large groupings of surgeonfish and many species of butterflyfish were seen in the vicinity, most on transect, and five *Lutjanus kasmira* were seen off transect. All other large fishes were captured on transect.

October 9, 2008

### **FFS-32**

*N 23 ° 48.366 W 166 ° 13.838*

This lagoon, patch reef site contained moderate live coral cover (19.2%) dominated by encrusting and moderately fissioned *Porites lobata* (48%). However, good coral diversity existed with 12 scleractinian species enumerated within survey area. Seven additional scleractinian species (*Acropora cytherea*, *A. humilis*, *Montipora incrassata*, *Leptastrea purpurea*, *Psammocora nierstraszi*, and *P. stellata*) were observed outside of transect. Many colonies of *Montipora capitata*, *M. patula*, and *Pocillopora* sp. exhibited mild to moderate bleaching. The algal community was dominated by *Lobophora variegata*, crustose coralline red algae, and turf algae with a low percent cover of highly epiphytized *Microdictyon setchellianum*, *Halimeda velasquezii*, *H. distorta*, and *H. discoidea*. *Caulerpa serrulata*. Non-geniculate branched coralline algae, a cyanophyte, a species of *Peyssonnelia*, *Halimeda gracilis*, *Dasya iridescens*, and *Dictyosphaeria versluysii* were documented on the Roving Diver survey.

This unique habitat had high diversity of invertebrate macrofauna. The ark shell, *Arca ventricosa*, was dominant in this complex habitat. Many caves, holes and overhangs existed at the site, which provided habitat for a variety of sessile encrusting organisms. The boring urchins, *Echinometra mathaei* and *Echinostrephus aciculatus*, were occasional. The sea cucumber, *Holothuria whitmaei*, the oyster, *Spondylus* sp., and the pearl oyster, *Pinctada margaritifera*, were rare. The invasive hydroid, *Pennaria disticha*, was present.

This site had moderate fish diversity and abundance, with both small and large fish sharing the territory. Large fish commonly recorded included *Acanthurus dussumieri*, *A. blochii*, *Naso unicornis*, *C. perspicillatus* and *Kyphosus* sp. A school of about two dozen tasty looking *Decapturus macarellus* swam through the transect area. Common smaller fish included *Acanthurus nigrofuscus*, *Ctenochaetus strigosus*, and *Thalassoma duperrey*. One *Caranx melampygus* was counted on transect, and one *C. ignobilis* was seen off transect.

### **FFS-R30**

*N 23 ° 51.522 W 166 ° 12.354*

This backreef site was mostly rubble with scattered *Porites lobata* and *Pocillopora* sp. Coral cover was extremely low (.8%). Interestingly, a 36-cm *Acropora cytherea* colony was growing amidst the rubble off transect. The majority of colonies were bleached, which is normal for this shallow exposed habitat. The algal community was dominated by turf algae with a low percent cover of highly grazed *Microdictyon setchellianum*. *Lobophora variegata*, crustose coralline red algae, *Dictyosphaeria cavernosa*, *Jania* sp., *Liagora* sp., and a gelid were also present. A non-geniculate coralline red algae and *Halimeda velasquezii* were documented on the Roving Diver survey. The boring urchin, *Echinometra mathaei*, was the dominant macroinvertebrate. The brittle stars, *Ophiocoma pica*, were large and abundant underneath the rubble. The unidentified sea cucumber commonly known as the “chocolate chip” sea cucumber was also common underneath large rubble pieces. *Tripneustes gratilla* were occasional. Fish diversity and abundance at this site were low, with wrasses being most common though not recorded in large numbers. Roughly a dozen large *Naso unicornis* were observed grazing within the second transect, greatly increasing this site’s fish biomass. Off transect, a single *Aprion virescens* cruised in for a look at the divers.

**FFS-R46**

N 23 °46.157 W 166 ° 15.704

This site was located on the south side of La Perouse Pinnacle. Coral cover was moderately high (42%) and mainly composed of encrusting *Porites lobata*. The coral community was diverse with colonies of *Acropora cytherea*, *A. humilis*, *Pavona varians*, *A. valida*, *Pocillopora meandrina*, *Montipora capitata*, *M. patula*, *Pavona duerdeni*, *Psammocora nierstraszi*, and *Porties brigham observedi*. The algal community was dominated by turf algae with crustose coralline red algae, *Lobophora variegata*, *Asparagopsis taxiformis*, and *Dictyota friabilis*. Species of *Peyssonnelia*, *Nemastoma*, *Sargasssum*, and *Martensia*, *Gibsmithia hawaiiensis*, *Halimeda velasquezii*, *Bryopsis pennata*, *Caulerpa racemosa*, and *C. webbiana* were documented on the Roving Diver survey. The boring urchin, *Echinostrephus aciculatus*, was the dominant macroinvertebrate. *Calcinus* hermit crabs and *Echinometra mathaei* were common. The bivalve, *Arca ventricosa*, and the nudibranch, *Pteraeolidia ianthina*, were common. Fish diversity and abundance were moderate with surgeonfish (*Acanthurus nigrofuscus*, *A. achilles*, *Naso lituratus*, and *Ctenochaetus strigosus*) being the most abundant fish in the area. *C. strigosus* and *A. nigrofuscus* were particularly abundant in the area, with numerous large representatives of each species encountered on all three transects. A few parrotfish such as *Scarus dubius* and *S. psittacus* were recorded on transect, but most were seen in the distance beyond transect boundaries. Seen off transect prowling the crevices and swim-throughs of the pinnacle were two whitetip reefs sharks, two ulua, and a few bluefin trevally.

**FFS-136**

N23 °49.686 W-166 °15.092

Depth: 16 m

This site is located in the northern area of the lagoon. It was established by the REA fish team as a new sampling location in the moderate lagoon stratum. Visibility was poor at approximately 35 feet with no current. The substrate was composed of rubble patches within a large sandy area, and *Porites compressa* beds mixed in the area. *Halimeda gracilis* formed a thick layer over the rubble that was not covered in *P. compressa*. Very few fish inhabited the *H. gracilis* beds, with *Oxycheilinus bimaculatus* being the most abundant species recorded on the first transect. The second transect, however, was laid over the *P. compressa*, so many more fish were encountered, *Scarus psittacus* being the most abundant. One *Caranx ignobilis* approximately 100 cm was counted on transect as well, while one *Aprion virescens* at 80 cm was seen off transect. Overall, fish abundance and diversity were low.

**FFS-240**

N 23° 50.945 W 166° 13.273

Depth: 26.5 m

This site was in the northwestern lagoon of French Frigate Shoals. It was established by the REA fish team as a new sampling location in the deep lagoon stratum. The bottom was flat and predominantly sand with *Codium edule* bunches and clusters. There was no coral cover at this site, and it was dominated by algae with 60% algal cover. There was a larger school of 50 or so *Naso unicornis* off transect at 40 cm, and several *Acanthurus olivaceus* at 35 cm. Rarely seen flame wrasses (*Cirrhitilabrus jordani*) were abundant on the second transect as well as spottail dart fishes (*Ptereleotris heteroptera*). There were also many twospot wrasses (*Oxycheilinus bimaculatus*) at this site. There were several large *Aprion virescens* on both of the transects, and a 5.5 ft grey reef shark off transect.



**FFS-242**

N 23° 50.945 W 166° 13.273

Depth: 8 m

This site was located in the northern lagoon of French Frigate Shoals. It was established by the REA fish team as a new sampling location in the moderate lagoon stratum. The site consisted of two large patches (about 20 m across each) of *Porites compressa* and *P. lobata* in the middle of a lagoonal sand flat. The coral areas had high complexity and relief due to the *P. compressa* and *P. lobata* mounds and had 80% coral cover in the non sand areas of the transects. The coral patches had high fish diversity and densities with 10 spp. of wrasses, 5 spp. of damselfish, 5 spp. of acanthurids, 4 spp. of goatfish, 3 spp. of scarids, 2 spp. of butterflyfish, and 1 spp. of jack. *Ctenochaetus strigosus*, scarids, *Dascyllus albisella*, *Chromis hanui*, *C. ovalis*, and *Mulloidichthys flavolineatus* were the most abundant species on the transects.

**FFS-244**

N 23° 49.276 W 166° 12.155

Depth: 11 m

This site was located in the lagoon of French Frigate Shoals. It was established by the REA fish team as a new sampling location in the moderate lagoon stratum. This site contained a large bed of *Porites compressa* that was approximately 60–70% live. Interspersed in the *P. compressa* were small patches of *Acropora*, *P. lobata* and *Montipora*, but not any of large quantity. There was low abundance and low diversity of fishes at this site, and mostly consisted of small parrotfish (*Chlorurus sordidus* and *Scarus dubius*). No large or rare fish were observed off transect.

**FFS-138**

N 23° 48.093W 166° 08.966

Depth: 11 m

This site was located in the lagoon of French Frigate Shoals. It was established by the REA fish team as a new sampling location in the moderate lagoon stratum. This site contained patches of *Porites compressa* coral beds among fine sand. The site was located on a moderate slope, but transects were aimed for consistent depths, so replicates included moderate stretches of sand (approximately 30%). There was moderate to high diversity at this site, with over 30 species of fish observed. The most common fishes were the parrotfish (*Chlorurus sordidus*, *Scarus dubius*) but also had large schools of *Dascyllus albisella* and *Mulloidichthys flavolineatus*. Only one off-transect sighting was observed of a large *Caranx ignobilis*.

**B.3. Benthic environment****B.3.1. Algae**

Benthic communities around French Frigate Shoals were dominated by turf algal, cyanobacteria and coral functional groups (Table B.3.1.1.). Coral was documented with the highest percent cover at 7 of the 14 sites surveyed. Turf algae percent cover exceeded that of other functional groups at 4 of the 14 sites and cyanobacteria were the dominant cover at 3 of the 14 sites (Table B.3.1.1.). A combined total of 32 species of macroalgae were observed (16 chlorophytes, 4 ochrophytes, 12 rhodophytes) from the 14 sites surveyed (Tables B.3.1.2., B.3.1.3.). *Lobophora variegata* dominated the macroalgal community at 5 of the 14 sites with a percent cover range of 0.4% to 23.6% (Table B.3.1.3.). *Microdictyon setchellianum* was the most prevalent macroalgal species at 4 of the 14 sites with a percent cover range of 0% to 30% across all sites (Table B.3.1.3.). *Halimeda velasquezii* was the most prevalent

species encountered at 4 of the 14 sites, and covered 0.4% to 27.6% of the substrate at 10 of the 14 sites (Table B.3.1.3.).

Table B.3.1.1. --Percent cover of algal functional groups at long-term monitoring sites at French Frigate Shoals.

Site	Macroalgae	Turf Algae	Coralline red algae (crustose + upright)	Cyanobacteria	Coral
FFS-R30	8.0%	0.8%	-	20.0%	70.4%
FFS-12	6.4%	81.6%	-	0.8%	11.2%
FFS-25	1.6%	20.0%	-	53.2%	24.4%
FFS-29	4.0%	21.6%	-	28.4%	43.2%
FFS-34	2.0%	3.6%	-	25.6%	67.2%
FFS-H6	-	36.4%	-	22.4%	40.4%
FFS-R46	6.8%	42.0%	0.4%	10.4%	40.0%
FFS-21	4.8%	59.2%	-	6.4%	29.6%
FFS-22	7.2%	1.6%	-	36.8%	29.2%
FFS-30	8.0%	24.8%	0.4%	31.6%	34.4%
FFS-32	8.0%	19.2%	-	44.8%	25.6%
FFS-33	2.0%	26.8%	-	29.2%	33.6%
FFS-35	3.6%	52.8%	0.4%	25.2%	16.8%
FFS-R29	10.8%	22.4%	0.4%	14.4%	40.0%

Table B.3.1.2.-- Additional species recorded at each site at French Frigate Shoals during Roving Diver survey.

Site	<b>Chlorophyta</b>
FFS-R46	<i>Bryopsis pennata</i>
FFS-R46	<i>Caulerpa racemosa</i>
FFS-30 FFS-33	<i>Caulerpa taxifolia</i>
FFS-21 FFS-33 FFS-R46	<i>Caulerpa webbiana</i>
FFS-33	<i>Caulerpella ambigua</i>
FFS-R29	<i>Dictyosphaeria cavernosa</i>
FFS-12 FFS-32 FFS-R29	<i>Dictyosphaeria versluysii</i>
FFS-12	<i>Halimeda discoidea</i>

Site	<b>Chlorophyta</b>
FFS-29 FFS-33 FFS-35	
FFS-32 FFS-35	<i>Halimeda gracilis</i>
FFS-22 FFS-R30 FFS-R46	<i>Halimeda velasquezii</i>
FFS-R29	<i>Microdictyon setchellianum</i>
FFS-12 FFS-25 FFS-29 FFS-33 FFS-34 FFS-35	<i>Neomeris sp.</i>
	<b>Ochrophyta</b>
FFS-R46	<i>Sargassum sp.</i>
FFS-22	<i>Turbinaria ornate</i>
	<b>Rhodophyta</b>
FFS-25	<i>Asparagopsis taxiformis</i>
FFS-30	<i>Chrysomenia sp.</i>
FFS-32 FFS-33	<i>Dasya iridescens</i>
FFS-35 FFS-R29 FFS-R46	<i>Gibsmithia hawaiiensis</i>
FFS-12 FFS-30	<i>Haloplegma duperreyi</i>
FFS-25 FFS-30 FFS-R29	<i>Jania sp.</i>
FFS-30	<i>Laurencia majuscula</i>
FFS-R46	<i>Martensia sp.</i>
FFS-35 FFS-R46	<i>Nemastoma sp.</i>
FFS-22 FFS-32 FFS-35 FFS-R46	<i>Peyssonnelia sp.</i>

Table B.3.1.3.-- Percent cover of macroalgal species at long-term monitoring sites at French Frigate Shoals. Sum totals for each row equal the percent cover of macroalgae recorded in Table B.3.1.1.

Site	<i>Caulerpa serrulata</i>	<i>Codium arabicum</i>	<i>Dictyosphaeria cavernosa</i>	<i>Dictyosphaeria versluysii</i>	<i>Halimeda discoidea</i>	<i>Halimeda distorta</i>	<i>Halimeda gracilis</i>	<i>Halimeda opuntia</i>	<i>Halimeda velasquezii</i>	<i>Microdictyon setchellianum</i>	<i>Neomeris</i> sp	<i>Asparagopsis taxiformis</i>	<i>Gelid</i>	<i>Haloplegma duperreyi</i>	<i>Jania</i> sp	<i>Laurencia majuscula</i>	<i>Liagora</i> sp	<i>Dictyota friabilis</i>	<i>Lobophora variegata</i>
FFS-R30	-	-	0.4%	0.4%	-	-	-	-	-	14.4%	-	-	0.8%	-	2.4%	-	0.4%	-	1.2%
FFS-12	-	-	-	-	-	-	-	-	-	-	0.4%	-	-	-	-	-	-	-	0.4%
FFS-25	-	-	-	-	3.2%	-	-	-	12.0%	30.0%	0.4%	-	-	-	-	-	-	-	7.6%
FFS-29	-	-	-	-	-	-	-	-	3.2%	1.6%	-	-	-	-	-	-	-	-	23.6%
FFS-34	-	-	-	-	0.4%	-	-	-	0.4%	16.4%	-	-	-	-	-	-	-	-	8.4%
FFS-H6	-	-	-	-	2.8%	-	-	-	12.0%	3.2%	0.4%	-	-	0.8%	-	-	-	-	3.2%
FFS-R46	-	-	-	-	-	-	-	-	-	-	-	2.8%	-	-	-	-	-	1.6%	6.0%
FFS-21	-	-	-	-	1.6%	-	-	-	4.4%	-	-	-	-	-	-	-	-	-	0.4%
FFS-22	-	-	-	0.4%	-	-	-	-	-	22.8%	-	-	0.4%	-	-	0.4%	0.8%	-	12.0%
FFS-30	-	-	-	-	2.0%	-	-	-	27.6%	-	-	-	-	-	-	0.4%	-	-	1.6%
FFS-32	0.4%	-	-	-	0.4%	2.0%	-	0.4%	9.6%	13.2%	-	-	-	-	-	-	-	-	18.8%
FFS-33	-	-	-	-	-	-	0.8%	-	8.0%	0.4%	-	-	-	-	-	-	-	-	20.0%
FFS-35	-	0.8%	-	-	-	-	-	2.4%	12.8%	2.4%	-	-	-	-	-	1.6%	-	-	5.2%
FFS-R29	-	-	-	0.4%	8.0%	-	-	0.4%	3.2%	-	-	-	-	-	-	-	-	-	2.4%

### B.3.2. Corals

#### B.3.2.1 Coral Populations

LPI surveys indicate that coral cover at REA sites around French Frigate Shoals in 2008 varied with both habitat and region. Mean coral cover was highest inside the lagoon ( $29.5 \pm 7.5\%$ ) and on the forereef ( $34.2 \pm 11\%$ ), while mean cover was extremely low in the backreef ( $0.8\%$ ) although only one site was surveyed.

Coral community structure varied both between and within habitats. French Frigate Shoals does not have a traditional lagoon as is the case for the northern atolls in the NWHI. REA sites that were considered lagoon habitat included FFS-30, -33, -32, 35, 22, and R29. Site 22 was a poorly developed shallow patch reef which was very different than the rest of the sites. Encrusting *Porites lobata* was the dominant coral at the remaining lagoonal sites, and coral cover ranged from moderate to moderately high.

Sites FFS-12 and -21 are located at the southwestern and northwestern corners of French Frigate Shoals and are composed of unique coral communities in which large tabular *Acropora cytherea* colonies are dominant. These two sites are unique and it would be interesting to investigate the physical factors that make these two geographically different sites so similar.

The forereef at French Frigate Shoals varied with location, but mostly was dominated by *Porites lobata* and *Pocillopora meandrina*. Site FFS-29, which has not been surveyed since 2002, was extremely diverse much more so than the other northern forereef site (FFS-H6).

The only backreef site surveyed consisted of mostly rubble with very few corals (*Porites*, *Pocillopora*, and *Leptastrea*).

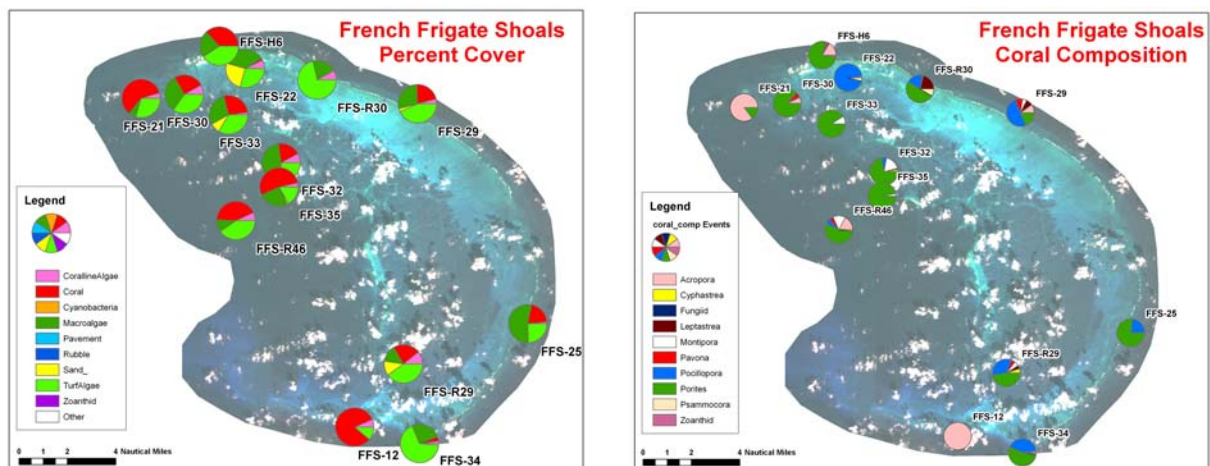


Figure B.3.2.1.1.--Spatial distribution of benthic cover and coral composition for REA sites at French Frigate Shoals in 2008.

Table B.3.2.1.1.--Relative percentage of coral taxon enumerated within belt transects for three habitat strata at French Frigate Shoals in 2008.

Lagoon		Forereef		Backreef	
Taxon	Percent	Taxon	Percent	Taxon	Percent
<i>Porites lobata</i>	58.4	<i>Acropora cytherea</i>	47.6	<i>Porites evermanni</i>	25.8
<i>Acropora cytherea</i>	22.3	<i>Porites lobata</i>	29.2	<i>Porites lobata</i>	21.6
<i>Porites evermanni</i>	5.3	<i>Pocillopora meandrina</i>	7.8	<i>Leptastrea purpurea</i>	20.7
<i>Porites compressa</i>	4.1	<i>Montipora patula</i>	4.4	<i>Pocillopora meandrina</i>	15.8
<i>Montipora capitata</i>	3.3	<i>Porites evermanni</i>	2.6	<i>Psammocora stellata</i>	8.3
<i>Pocillopora damicornis</i>	1.6	<i>Pavona duerdeni</i>	2.0	<i>Pocillopora damicornis</i>	3.1
<i>Montipora patula</i>	1.1	<i>Pocillopora eydouxi</i>	1.6	<i>Porites compressa</i>	2.7
<i>Pocillopora meandrina</i>	1.0	<i>Acropora valida</i>	1.2	<i>Pavona duerdeni</i>	1.4
<i>Pavona duerdeni</i>	0.8	<i>Leptastrea purpurea</i>	1.1	<i>Cyphastrea ocellina</i>	0.7
<i>Cyphastrea ocellina</i>	0.7	<i>Palythoa</i> sp.	0.6		
<i>Acropora humilis</i>	0.4	<i>Psammocora nierstraszi</i>	0.5		
<i>Leptastrea purpurea</i>	0.4	<i>Pavona varians</i>	0.3		
<i>Pocillopora</i> sp	0.2	<i>Porites brighami</i>	0.3		
<i>Porites brighami</i>	0.2	<i>Montipora capitata</i>	0.3		
<i>Pavona varians</i>	0.1	<i>Cyphastrea ocellina</i>	0.2		
<i>Pocillopora ligulata</i>	0.1	<i>Montipora incrassata</i>	0.2		
<i>Psammocora stellata</i>	0.1	<i>Pocillopora ligulata</i>	0.1		
<i>Palythoa</i> sp.	0.1	<i>Porites</i> sp	0.1		
	0.0	<i>Psammocora stellata</i>	0.1		

#### B.3.2.2. Coral Disease

During 2008 REA surveys, there were moderate levels of compromised coral health states. Coral bleaching was observed as the most common type of compromised health conditions at all three reef habitats (Fig. B.3.2.2.1.). Bleaching was particularly prevalent in the backreef, affecting 100% of *Porites compressa* colonies, as well as 75% of *P. lobata* and *Pocillopora meandrina* colonies (Fig. B.3.2.2.1.). In forereef and lagoon habitats, *Montipora capitata* and *M. patula* colonies were the most common species to exhibit signs of coral bleaching (Fig. B.3.2.2.1.). While coral bleaching was the only example of compromised coral health found in the backreef sites, hyperpigmentation, algal interactions, pink line syndrome and subacute tissue loss were found among various species throughout the forereef and lagoonal sites (Fig. B.3.2.2.2.). Hyperpigmentation was found to affect mostly *Montipora patula* colonies. *Porites evermanni* and *P. lobata* showed signs of pink line syndrome, and algal interactions affected *M. capitata*, *P. compressa*, and *P. evermanni*. Percent mortality of colonies surveyed during 2008 varied among reef habitat type. In the backreef, members of the genus *Porites* were found to have about 25% dead tissue present of colonies along the belt transect. Throughout forereef sites, *Leptastrea* and *Psammocora* colonies had 28.3 and 19.4% partial mortality, respectively. *Leptastrea*, *Pavona*, and *Acropora* species were found to have ~ 25% dead tissue at lagoonal sites.

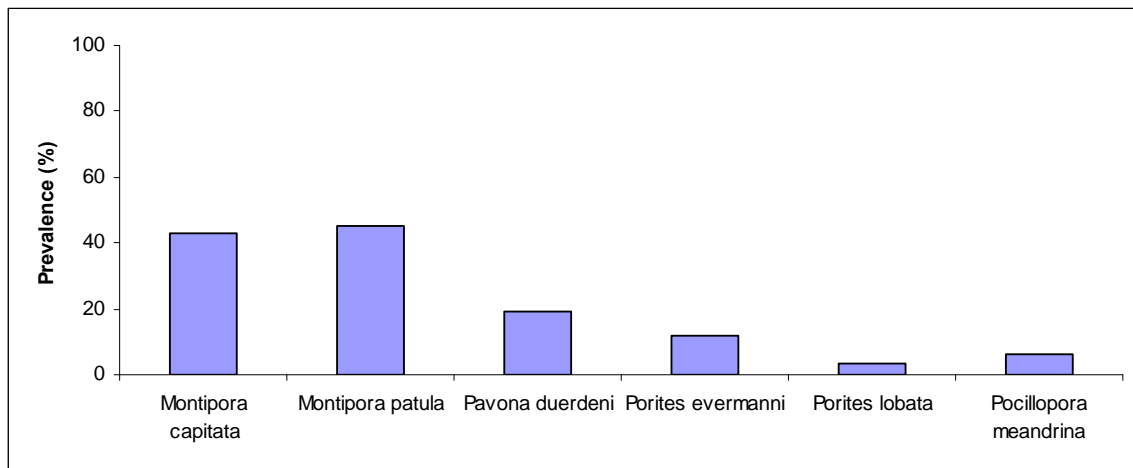
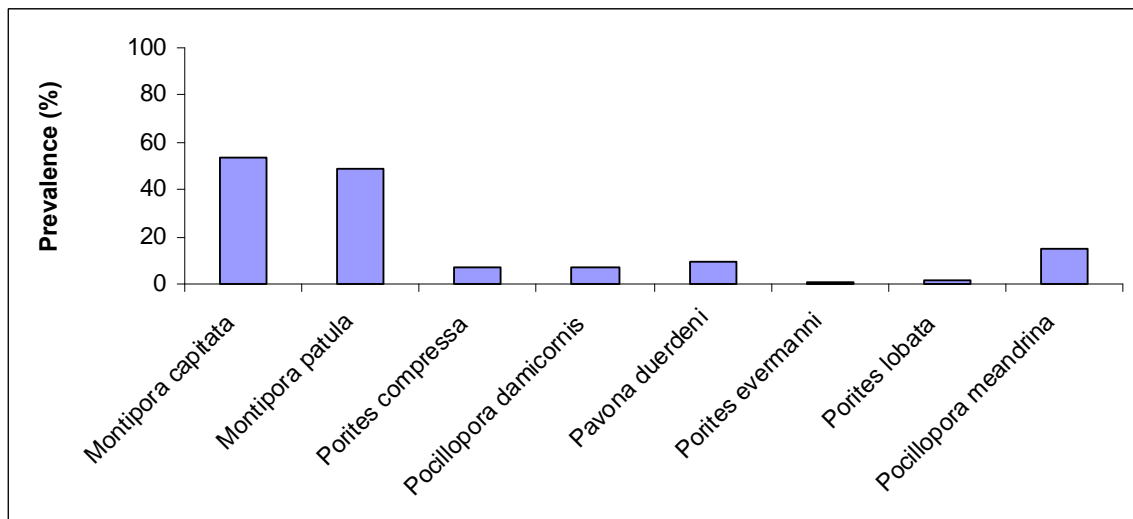
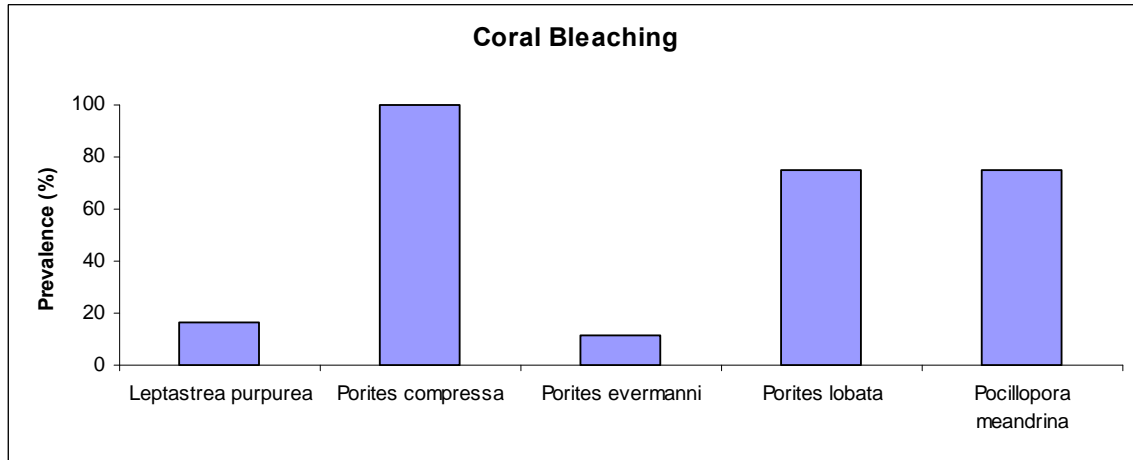


Figure B.3.2.2.1.--Prevalence of bleached coral taxa at French Friagate Shoals in 2008.  
Top: Backreef. Middle: Forereef. Bottom: Lagoon.

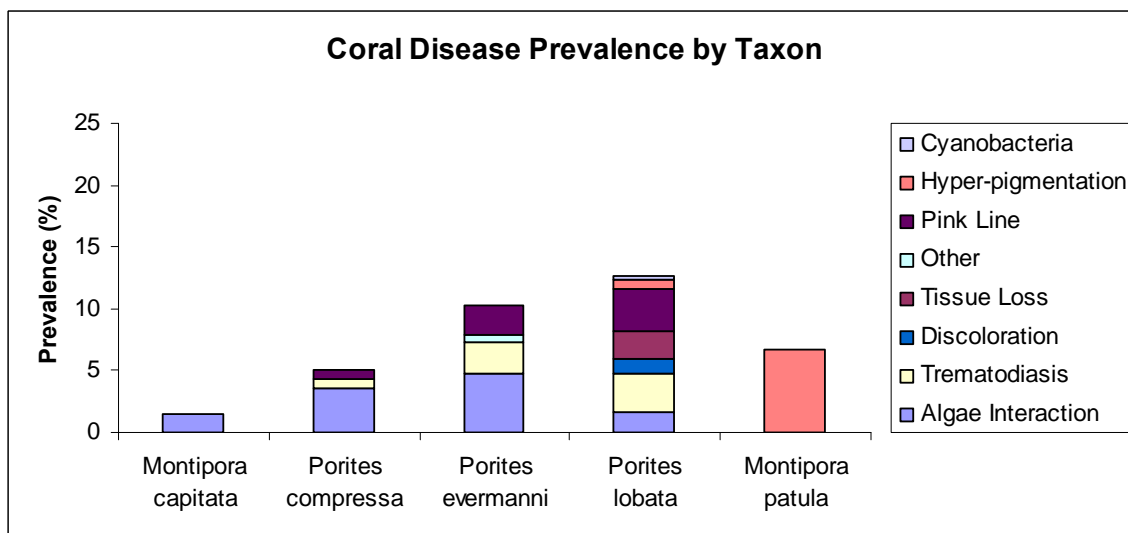
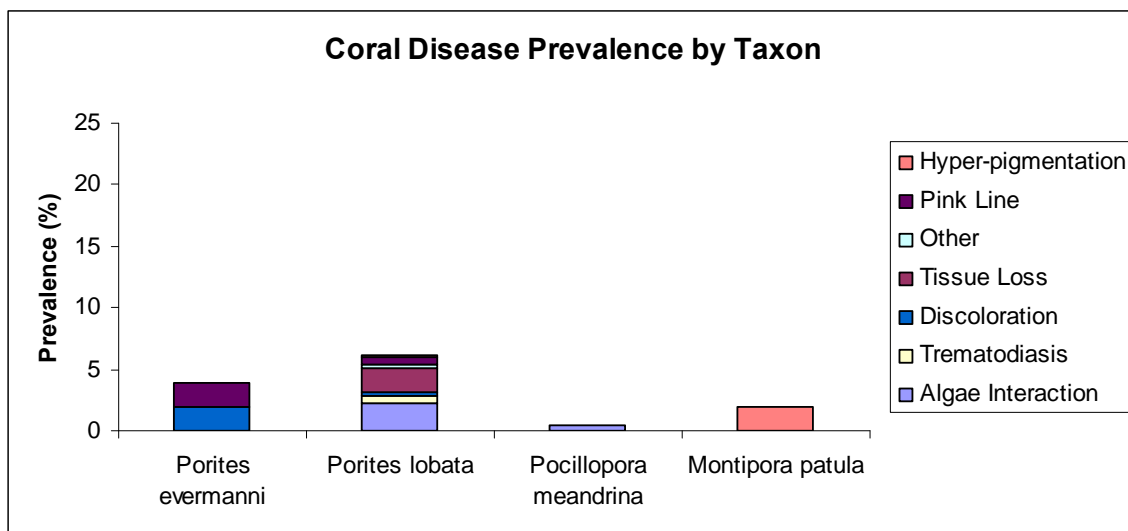


Figure B.3.2.2.2.--Prevalence of coral disease by taxa at French Friagate Shoals in 2008. Top: Forereef. Bottom: Lagoon. There was no disease recorded in the backreef.



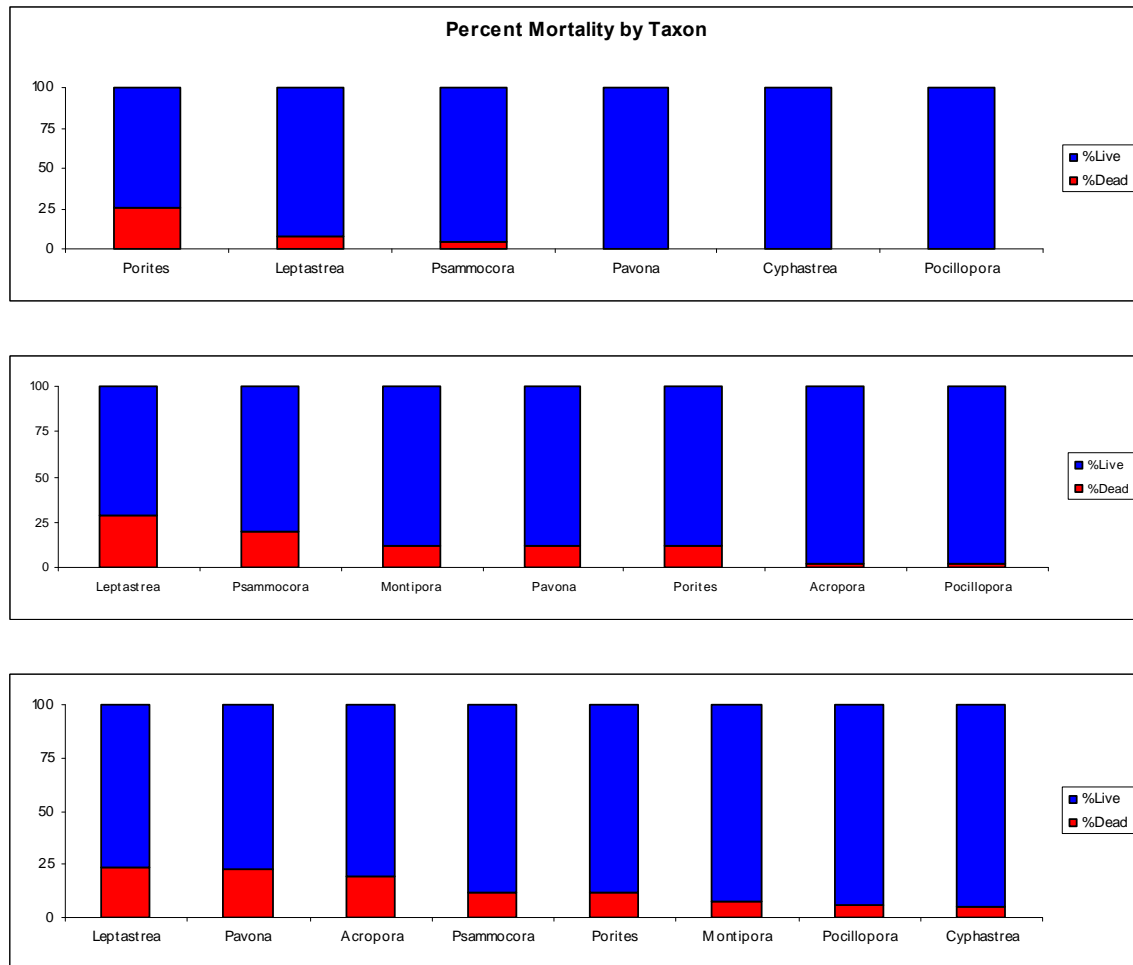


Figure B.3.2.2.3.--Mean percent live versus dead tissue for various coral genera at French Frigate Shoals in 2008. Top: Backreef. Middle: Forereef. Bottom: Lagoon.

### B.3.3. Non-coral Invertebrate Surveys

A total of 1696 individuals of benthic invertebrate target species or taxa group were enumerated from 28 belt transects at 14 sites. The sea urchin, *Echinostrephus aciculatus*, was the most abundant benthic invertebrate in forereef sites ( $n = 6$ ) and *Echinometra mathaei* was the most abundant benthic invertebrate in backreef ( $n = 1$ ) (mean density 1.42 and 0.83/m<sup>2</sup>, respectively). However, both were low at lagoon sites (*E. aciculatus* 0.10/m<sup>2</sup> and *E. mathaei* 0.01/m<sup>2</sup>). The forereef site, FFS-29, had the highest density of *Echinostrephus aciculatus* with 3.95/m<sup>2</sup>. In addition, trapezid crabs (0.95/m<sup>2</sup>), *Coralliophillidae* snails (0.60/m<sup>2</sup>), and *Calcinus* hermit crabs (0.33/m<sup>2</sup>) were prevalent at site FFS-29. The polychaete, *Loimia medusa*, was common at the lagoon site FFS-22 with a density of 0.13/m<sup>2</sup>. The unidentified *Holothuria* sp. commonly known as the “chocolate chip sea cucumber,” was common at the backreef site, FFS-R30 with a density of 0.06/m<sup>2</sup>, and the brittle star, *Ophiocoma erinaceus*, was abundant at the same site underneath the rubble. The bivalve, *Arca ventricosa*, was abundant at site FFS-R46, FFS-R29 and FFS-32. The invasive hydroid, *Pennaria disticha*, was found at site FFS-32, FFS-R29, and FFS-34.

### B.3.3.1. Urchin Measurements

Figure B.3.3.1.1. reveals the average test diameter of urchins encountered at each site. Only sites where  $\geq 5$  measurements were recorded for a species are represented.

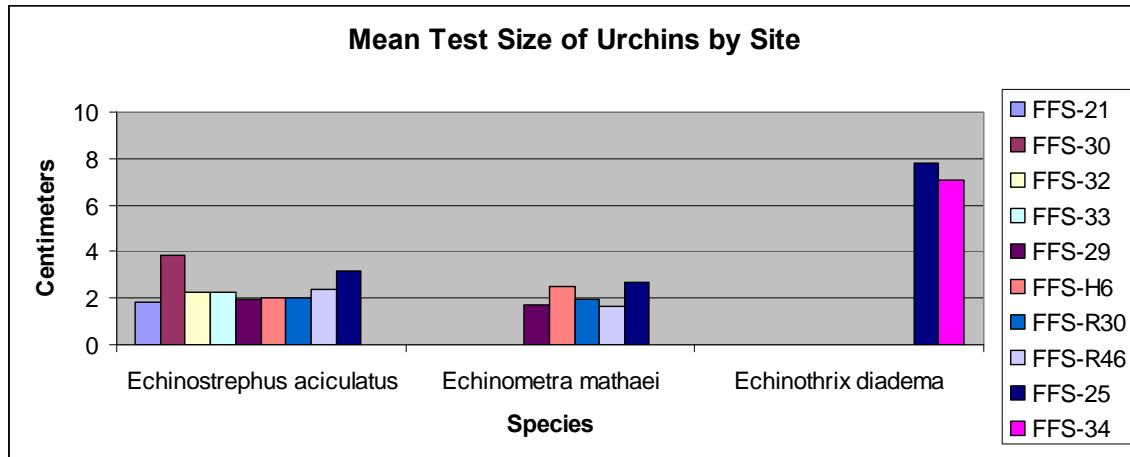


Figure B.3.3.1.1.--Mean test size of urchins by site.

Figure B.3.3.1.2. reveals the average test diameter of urchins by stratum. Only stratum where  $\geq 5$  measurements were recorded for a species are represented.

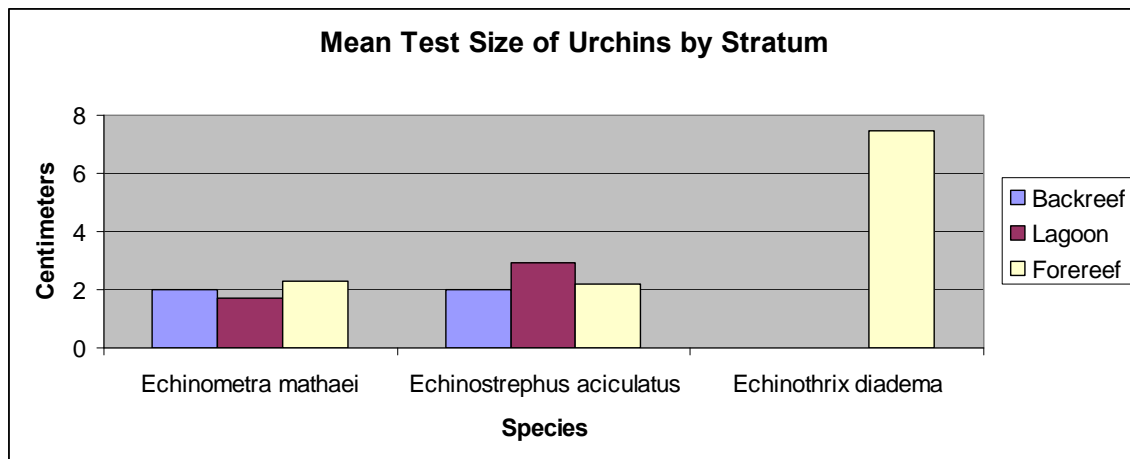


Figure B.3.3.1.2.-- Mean test size of urchins by stratum.

### B.3.3.2. ARMS Deployment

ARMS were deployed at the following REA sites around French Frigate Shoals. Each site contains three ARMS.

Table B.3.3.2.1.--ARMS deployment locations around French Frigate Shoals.

REA Site	Latitude	Longitude
FFS-12	23° 38.301 N	-166° 10.803 W
FFS-H6	23° 52.807 N	-166° 16.388 W
FFS-34	23° 37.675 N	-166° 08.123 W
FFS-35	23° 47.437 N	-166° 13.921 W
FFS-33	23° 50.188 N	-166° 16.010 W
FFS-32	23° 48.366 N	-166° 13.838 W

#### B.3.4 Towed-diver Benthic Surveys

The 26 towed-diver benthic habitat surveys of French Frigate Shoals were conducted along the outlying forereef habitats atoll-wide, along sections of the central and southern lagoons and in areas of the eastern, northeastern, and northern backreefs.

The overall averages for substrate composition and macroinvertebrate population densities are illustrated in the tables below (Tables B.3.4.1, B.3.4.2.).

Table B.3.4.1.--Overall benthic habitat composition.

Substrate	Percent Cover (%)	Percent Cover Range (%)
Hard Coral	15.83	0–75
Stressed Hard Coral	3.19	0–20
Soft Coral	0.29	0–10
Sand	16.06	0–100
Rubble	18.74	0–100
Macroalgae	17.66	0–100
Coralline algae	8.99	0–40

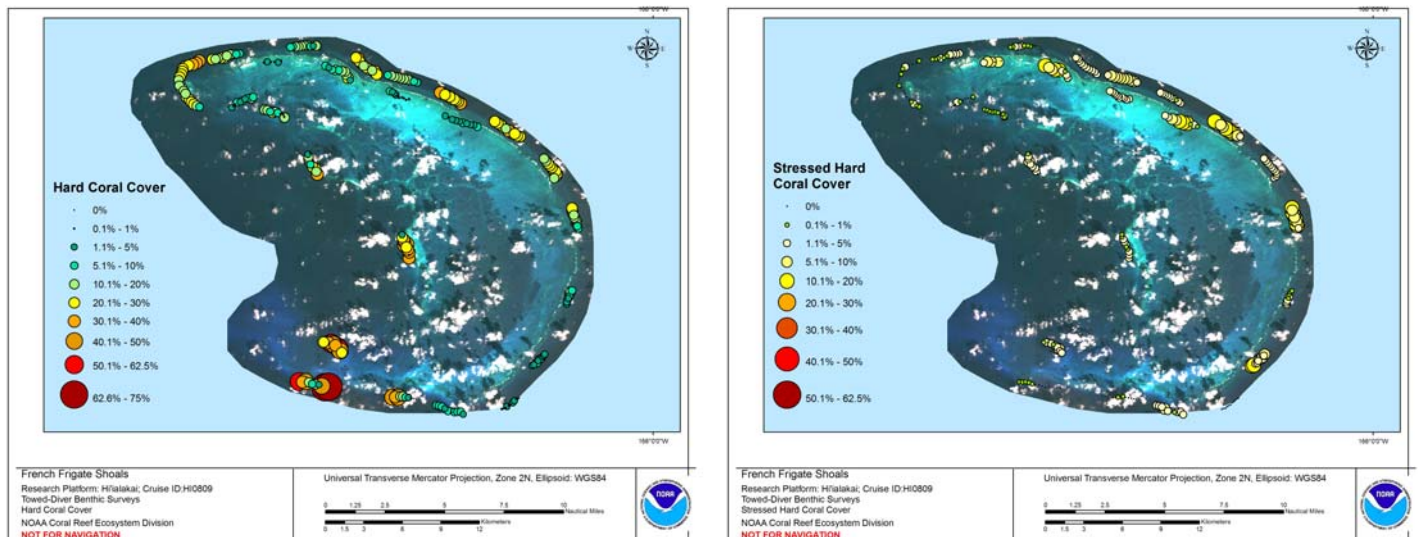
Habitat within the lagoon consisted primarily of continuous reef and patch reefs in rubble and sand flats. Forereef consisted of a mix between continuous reef, spur and groove/pavement, sand flats, rubble flats, and occasional patch reefs (esp. in the south). Finally, backreef habitat consisted primarily of sand and rubble flats, interspersed with patch reefs and the occasional stretch of continuous reef.

Table B.3.4.2.--Overall macroinvertebrate population densities.

Macroinvertebrate	Density (#/hectare)	Total # Observed
<i>Acanthaster Planci</i> (COTs)	1.70	96
Boring sea urchins	677.41	38,274
Free-living sea urchins	23.06	1,303
Sea Cucumbers	38.09	2,152

Hard coral cover averaged 15.83% (range 0–75%), with the highest coral cover recorded at 41.38% (20.1–62.5%) during a deeper towe-diver survey in the central southern lagoon. Coral cover consisted primarily of *Porites compressa* and *Porites lobata*. An additional area of interest and high coral cover occurred along the southern/southwestern

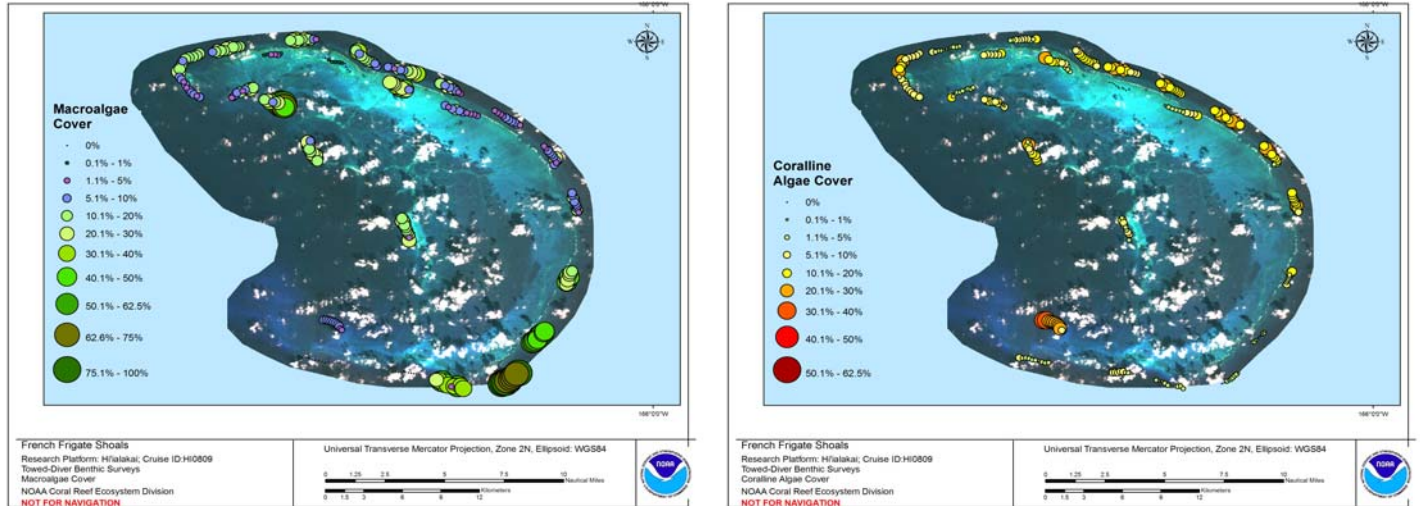
forereef during a (new) towed-diver survey, where large, monotypic stands of *Acropora cytheria* interspersed with *Porites lobata* averaged 35.88% (range 1.1–75%).



Figures B.3.4.1. and B.3.4.2.--Hard corals and stressed coral cover.

Coral stress averaged 3.19% (range 0–20%), with coral stress primarily associated with paling/bleaching of *Montipora* colonies (sometimes whole colonies, when small) and paling of *Pocillopora* colonies (esp. tips). The highest coral stress was found (1.1–20%) on the eastern forereef, working northwestward (counterclockwise). COT predation and paling/bleaching of *Pocillopora* colonies were identified as the potential sources of the observed coral stress during this tow.

Macroalgae cover averaged 17.66% (range 0–100%) island wide. The highest macroalgae cover averaged 78.13% (range 62.5–100%) along a portion of the southeastern forereef, which was largely composed of pavement reef and what appeared to be consolidated/fused rubble. *Microdictyon setchellianum* essentially carpeted the bottom, with *Liagora* and *Halimeda* species providing additional cover. Coralline algae averaged 8.99% (range 0–40%), with the highest cover noted in the southern lagoonal continuous reefs (average 25.25%, range 5.1–40%).



Figures B.3.4.3. and B.3.4.4.--Macroalgae and coralline algae cover.

A total of 96 COTS were encountered during the pooled towed-diver surveys at French Frigate Shoals, with an overall average of 1.70 COTS/ha<sup>-1</sup>. COTS counts were highest along the eastern forereef, with 24 COTS counted during one 50-min survey. COTS numbers were generally low, during all other towed-diver surveys around French Frigate Shoals. Boring sea urchin densities averaged ~677.41/ha<sup>-1</sup> and were highest during a towed-diver survey conducted along the northern forereef, with 5 time segments recording 750 urchins, and 3 time segments recording > 1001 boring urchins. Free urchins were relatively less common at 23.06 urchins/ha<sup>-1</sup> overall. Finally, sea cucumber populations averaged around 36/ha<sup>-1</sup>, with the highest numbers encountered (612) encountered during a towed-diver survey of the northeastern backreef.

## B.4 Fish

### B.4.1 REA Fish Surveys

#### *Belt transect data*

During the survey period, 77 belt transect surveys were conducted at 32 sites around French Frigate Shoals. Surgeonfish (Acanthuridae) were the largest contributor to total biomass with 39.32 kg 100 m<sup>-2</sup>. Snappers (Lutjanidae) were the second largest contributor to total biomass with 13.58 kg 100 m<sup>-2</sup> followed by parrotfish (Scaridae) and jacks (Carangidae) at 11.41 kg 100 m<sup>-2</sup> and 10.15 kg 100 m<sup>-2</sup>, respectively (Table B.4.1.1.).

#### *Overall observations*

A total of 138 fish species were observed during the survey period by all divers. The average total fish biomass at the sites at French Frigate Shoals during the survey period was 18.47 kg 100 m<sup>-2</sup> for the belt transect surveys (Table B.4.1.2.).

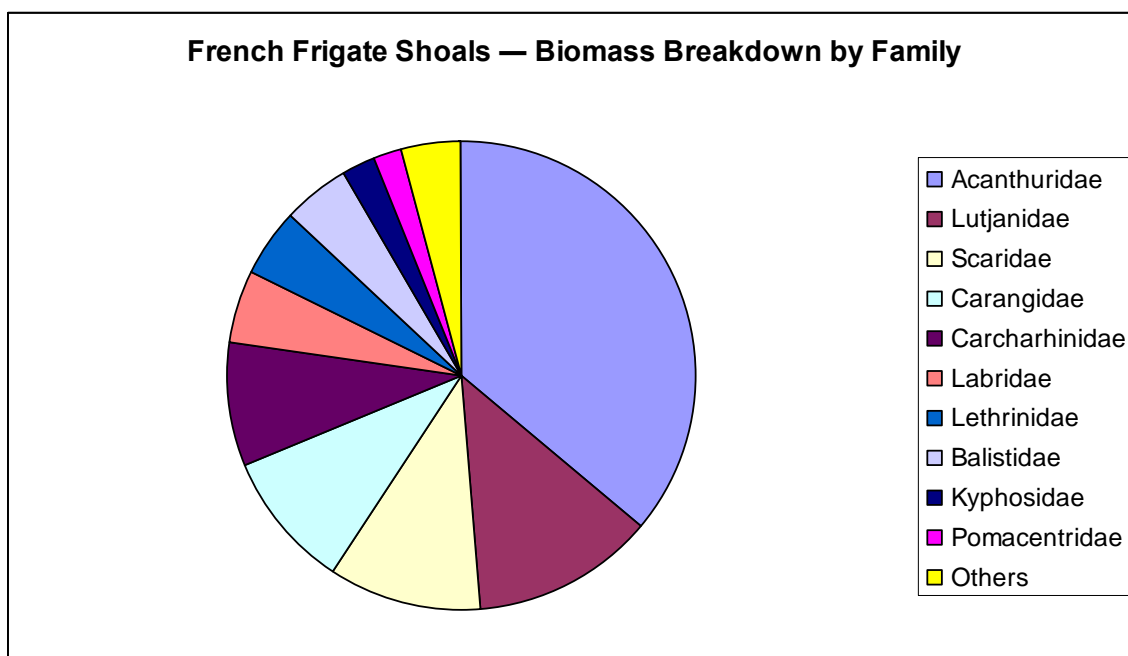


Figure B.4.1.1.--Total fish biomass composition by family.

<b>Table B.4.1.2.--Coral reef fish biomass (kg 100 m<sup>-2</sup>) by family at sites around French Frigate Shoals.</b>													
<b>Stratum – Depth</b>	<b>Site</b>	<b>Total</b>	<b>Acanth.</b>	<b>Balistid</b>	<b>Carangid</b>	<b>Carchar.</b>	<b>Kyphos.</b>	<b>Labrid</b>	<b>Lethrin.</b>	<b>Lutjanid</b>	<b>Pomacen.</b>	<b>Scarid</b>	<b>Others</b>
Forereef – Deep	FFS-241	19.94	12.64	1.87	0.90			0.89	2.38	0.98	0.00		0.28
Forereef – Mid	FFS-12	28.11	0.73	1.27	2.52		0.03	0.67	5.19	10.56	1.22	0.51	5.41
	FFS-232	17.72	1.79	1.09	6.87	0.40		0.27	1.97	2.39	0.04	1.28	1.63
	FFS-234	26.76	23.77	0.22				1.15		0.78	0.01	0.66	0.17
	FFS-235	61.75	15.66	3.16	6.87	31.62		0.48		3.00	0.23	0.17	0.57
	FFS-25	23.04	16.61	1.00				0.98		1.33	0.80	1.26	1.05
	FFS-29	38.68	3.77	3.14	14.56	13.87		1.26			0.45	1.03	0.61
	FFS-34	4.48	3.34	0.63				0.30			0.13		0.08
	FFS-H6	1.45	0.29	0.19	0.26			0.22			0.22	0.14	0.12
	FFS-R46	8.18	2.96	1.99	0.65		0.39	0.22			0.25	1.55	0.17
Forereef – Shallow	FFS-229	11.57	10.00	0.06				1.25			0.09		0.17
	FFS-228	35.02	12.83	0.32	2.92		3.73	1.40	2.40	1.46	1.05	7.82	1.09
Lagoon – Deep	FFS-240	8.44	0.23	0.01				1.07		6.64			0.49
	FFS-250	15.57	0.85					0.57	1.27	9.70	0.07	2.40	0.72
	FFS-252	16.70	0.91	0.26				0.95		7.61	0.98	4.39	1.60
Lagoon – Mid	FFS-136	9.20	2.30		5.17			0.28			0.06	1.13	0.26
	FFS-138	17.53	0.30					1.68			3.27	10.00	2.27
	FFS-21	6.23	1.60	1.91	0.18			0.46			0.02	1.72	0.33
	FFS-242	27.79	1.11		14.70			2.44		0.98	2.81	3.12	2.63
	FFS-243	61.84	1.94			55.31		0.78		1.76	0.01	1.13	0.91
	FFS-244	5.19	0.06					0.32			0.06	4.60	0.14
	FFS-245	13.51	4.30					0.77			1.88	2.39	4.16
	FFS-247	16.06	1.06		7.41			0.39			0.01	6.71	0.48
	FFS-248	9.42	5.64					0.38		0.32	0.04	2.57	0.46
	FFS-32	19.91	9.20	0.46	1.80		4.30	1.07			0.30	1.94	0.84
	FFS-33	10.02	2.33		5.58			0.63		0.31	0.08	0.93	0.17
	FFS-35	11.61	7.34	0.82	0.26			0.50			0.23	2.21	0.25
	FFS-R29	10.48	2.13					1.31				4.42	2.63
Lagoon – Shallow	FFS-22	1.72	0.05					0.74		0.65	0.03	0.02	0.22
	FFS-226	25.86	5.37	5.69	2.72		1.16	2.23	2.29	3.11	0.08	2.30	0.90
	FFS-30	10.88	1.77	0.44	4.37		0.03	0.37		1.80	0.04	1.77	0.30
	FFS-R29	26.48	11.39		1.44		0.11	2.10		3.78	0.96	5.51	1.18
	FFS-R30	8.28	7.15					0.45		0.65		0.00	0.02
<b>Average</b>		<b>18.47</b>	<b>5.19</b>	<b>1.29</b>	<b>4.40</b>	<b>25.30</b>	<b>1.39</b>	<b>0.87</b>	<b>2.58</b>	<b>3.04</b>	<b>0.51</b>	<b>2.54</b>	<b>0.98</b>

#### B.4.2 Towed-diver Fish Surveys

During the 2008 RAMP mission, the CRED towboard team completed 26 surveys at French Frigate Shoals covering 56.5 km (56.5 ha) of ocean floor (Table B.4.2.1.). Mean survey length was 2.2 km with a maximum length of 2.9 km and a minimum of 1.4 km. Mean survey depth was 11.5 m with a maximum depth of 17.1 m and a minimum of 1.8 m in the backreef. Mean temperature on these surveys was 27.6 °C with a maximum temperature of 28.3 °C and a minimum of 26.9 °C.

Table B.4.2.1.--Survey statistics for towboard sampling during HI0809.

Island/Atoll/Reef #		Length (km)					Depth (m)				Temperature (°C)			
		Sum	Mean	Max	Min	SD	Mean	Max	Min	SD	Mean	Max	Min	SD
Kure	14	32	2.3	2.7	1.8	0.02	8.2	16.5	0.9	5.9	26.8	27.3	25.5	0.4
Midway	16	39	2.4	3.2	1.9	0.03	9	16.9	0.7	5.9	27.2	28	26.9	0.3
Pearl & Hermes	27	63	2.3	3.1	1.3	0.03	10.3	16.3	1.2	5.2	27.3	27.9	26.8	0.3
Lisianski	12	24.7	2.1	2.3	1.7	0.02	10	14.2	1.6	3.9	28	28.2	27.8	0.1
Laysan	5	11.5	2.3	2.5	2.1	0.01	11.8	13.6	9.2	1.5	27.9	28	27.8	0.1
Maro Reef	11	23.4	2.1	2.4	1.7	0.01	13.3	16.5	9.5	1.8	28.2	28.4	27.9	0.1
French Frigate	26	56.5	2.2	2.9	1.4	0.03	11.5	17.1	1.8	4.5	27.6	28.3	26.9	0.2

Three hundred twenty-nine individual large-bodied reef fish (> 50 cm TL) of 22 different species and 12 different families were encountered at French Frigate Shoals (Table B.4.2.2.). Overall numeric density for this class of reef fishes was 0.058 #/100m<sup>2</sup> (5.824 #/ha) with a biomass density of 0.51 kg/100m<sup>2</sup> (0.051 t/ha). Numeric density was dominated by *Aprion virescens* while biomass density was dominated by *Caranx ignobilis*.

The most prevalent families in terms of numeric density were Carangids (29%), Lutjanids (25%), Carcharhinids (19%), and Acanthurids (13%) (Fig. B.4.2.1.). Biomass was dominated by Carangids (39%), Carcharhinids (35%), and Lutjanids (18%). (Fig. B.4.2.2.).

Numeric and biomass densities for large bodied reef fish were higher on the forereef compared to the backreef and lagoon areas of French Frigate Shoals (Fig. B.4.2.3.). Biomass appears to be fairly evenly distributed around the forereef with only a few surveys along the far eastern section of the reef having low values for numbers and biomass. Biomass values for *Caranx ignobilis* and *Carcharhinus amblyrhynchos* were highest along the northern portion of the forereef. *Aprion virescens* was fairly evenly distributed with particularly high values in the southeast.



Table B.4.2.2.--Species numeric and biomass density for large-bodied reef fish (> 50 cm TL) observed at French Frigate Shoals during 2008 CRED towed-diver surveys.

Species	#	#/100m2	#/ha	Biomass (kg)	kg/100m2	t/ha
Aetobatus_narinari	4	0.001	0.071	61.843	0.011	0.001
Aphareus_furca	6	0.001	0.106	8.831	0.002	0.000
Aprion_virescens	76	0.013	1.345	501.879	0.089	0.009
Aulostomus_chinensis	2	0.000	0.035	0.393	0.000	0.000
Carangoides_orthogrammus	7	0.001	0.124	25.521	0.005	0.000
Caranx_ignobilis	52	0.009	0.920	998.510	0.177	0.018
Caranx_melampygus	17	0.003	0.301	45.583	0.008	0.001
Caranx_sexfasciatus	15	0.003	0.266	35.146	0.006	0.001
Carcharhinus_amblyrhynchos	42	0.007	0.743	372.050	0.066	0.007
Carcharhinus_galapagensis	1	0.000	0.018	108.800	0.019	0.002
Coris_flavovittata	1	0.000	0.018	4.400	0.001	0.000
Fistularia_commersonii	4	0.001	0.071	3.393	0.001	0.000
Gymnothorax_flavimarginatus	1	0.000	0.018	7.798	0.001	0.000
Gymnothorax_meleagris	3	0.001	0.053	6.300	0.001	0.000
Monotaxis_grandoculis	20	0.004	0.354	64.916	0.011	0.001
Naso_brevirostris	2	0.000	0.035	6.888	0.001	0.000
Naso_caesius	1	0.000	0.018	2.787	0.000	0.000
Naso_hexacanthus	34	0.006	0.602	72.119	0.013	0.001
Naso_unicornis	6	0.001	0.106	15.405	0.003	0.000
Parupeneus_cyclostomus	3	0.001	0.053	4.650	0.001	0.000
Scarus_rubroviolaceus	11	0.002	0.195	30.440	0.005	0.001
Triaenodon_obesus	21	0.004	0.372	502.411	0.089	0.009
Grand Total	329	0.058	5.824	2880.063	0.510	0.051
# of Species	22					

**Numeric Density Contribution by Family for Large-Bodied Reef Fish (>50cmTL) observed at French Frigate Shoals During 2008 CRED Towed-Diver Surveys**

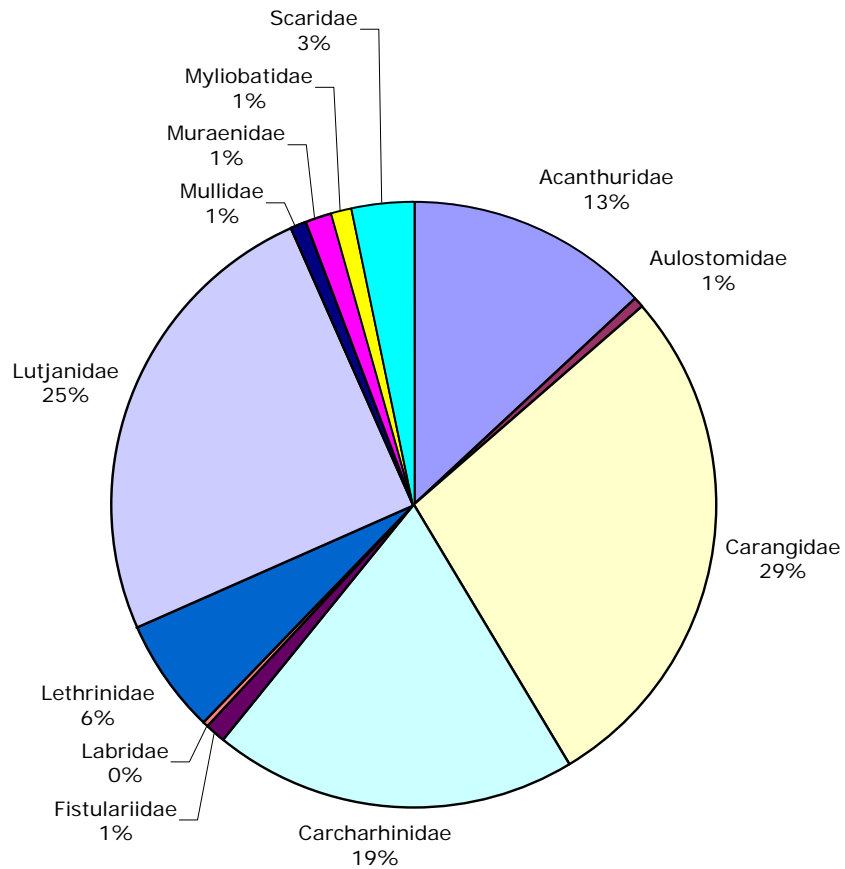


Figure B.4.2.1.--Numeric density of observed fish by family at French Frigate Shoals.

**Biomass Density Contribution by Family for Large-Bodied Reef Fish (>50cmTL) observed at French Frigate Shoals During 2008 CRED Towed-Diver Surveys**

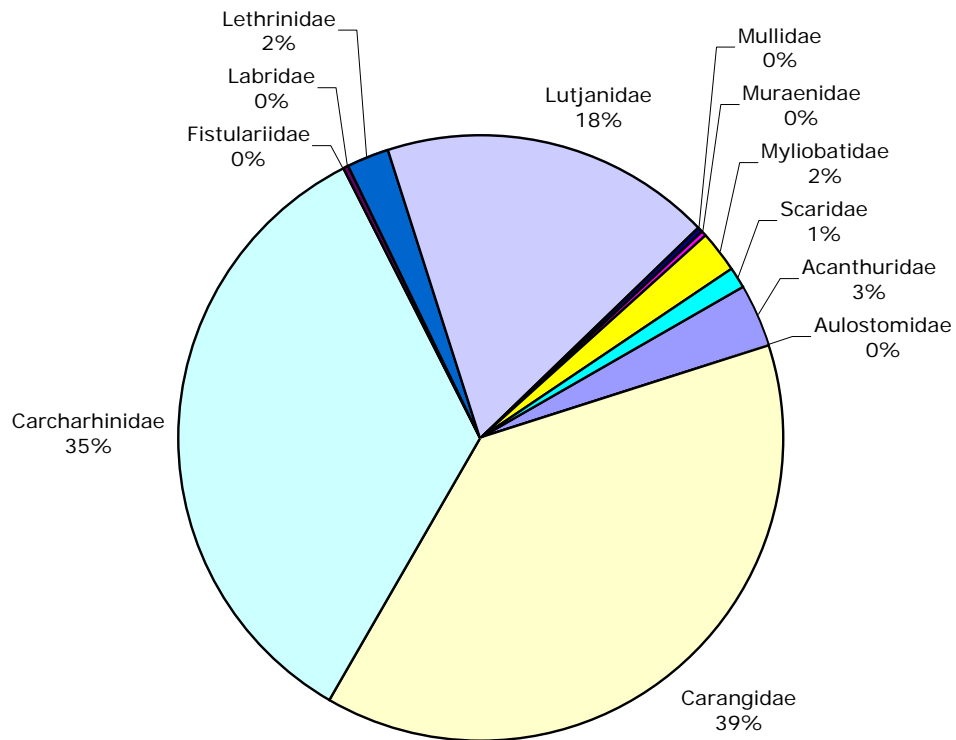


Figure B.4.2.2.--Biomass density of observed fish by family at French Frigate Shoals.

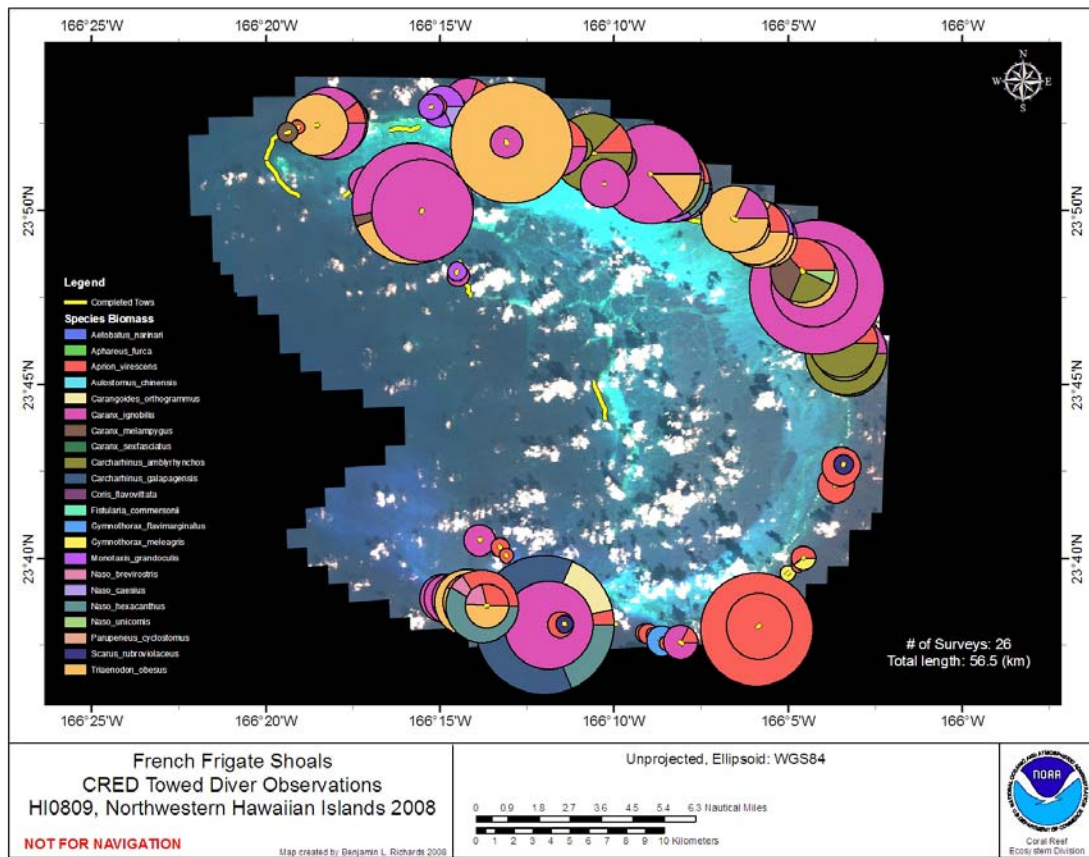


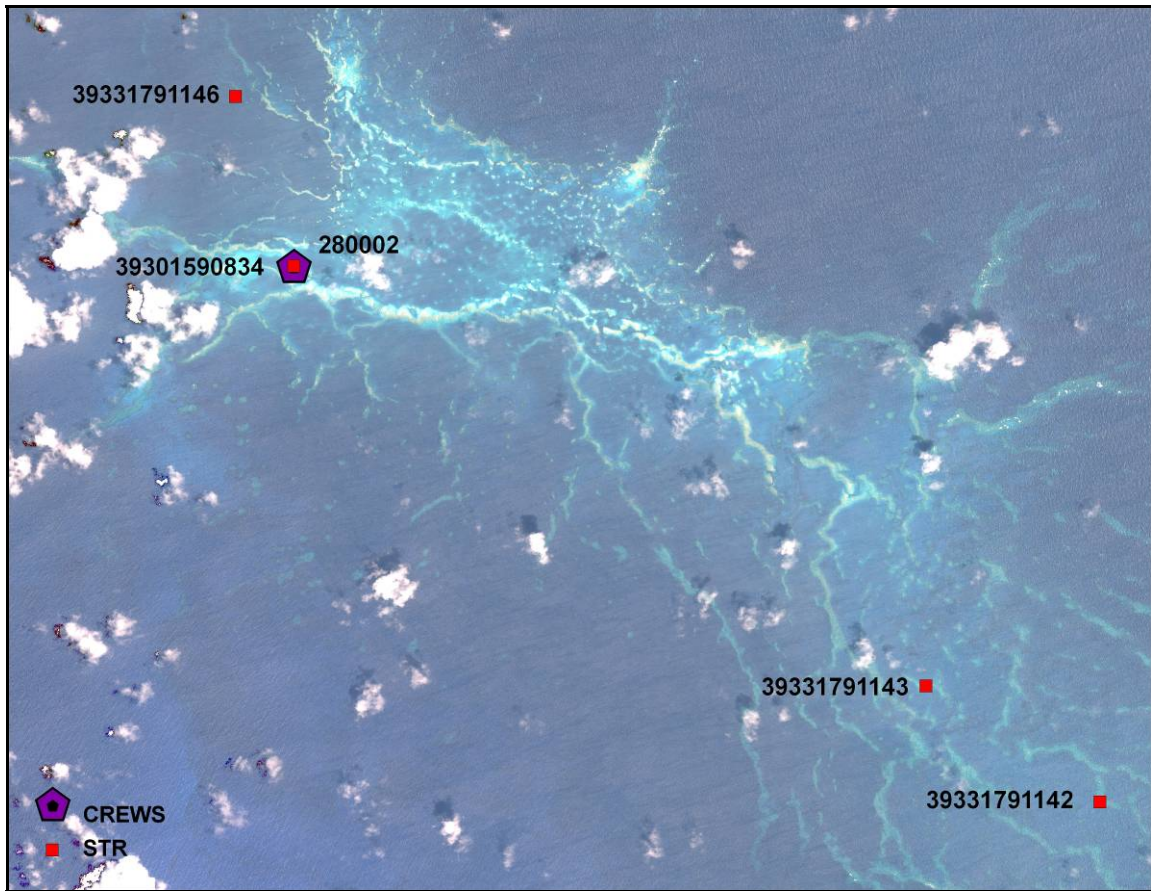
Figure B.4.2.3.--Geographic distribution of biomass around French Frigate Shoals. Each species is represented by a legend color. Diameter of pie chart is proportional to total biomass of all species encountered on the underlying survey.

## **Appendix C: Maro Reef**

### C.1. Oceanography and Water Quality

#### Moorings (Fig. C.1.1., Table C.1.1.)

Five subsurface temperature recorders (STRs) were deployed at Maro Reef, including one new deployment, and four STRs were recovered during HI0809. Three of these were stand alone STRs that were recovered and replaced; two accompanied other instrumentation. A Coral Reef Early Warning System (CREWS) buoy was removed and replaced by an sea surface temperature (SST) buoy with an STR on its anchor. A new ecological acoustic recorder (EAR) and STR were deployed together on the northwestern side of the reef (Fig. C.1.1.). This EAR was deployed to monitor both biological acoustics as well as reported vessel traffic around the reef and in the lagoon.





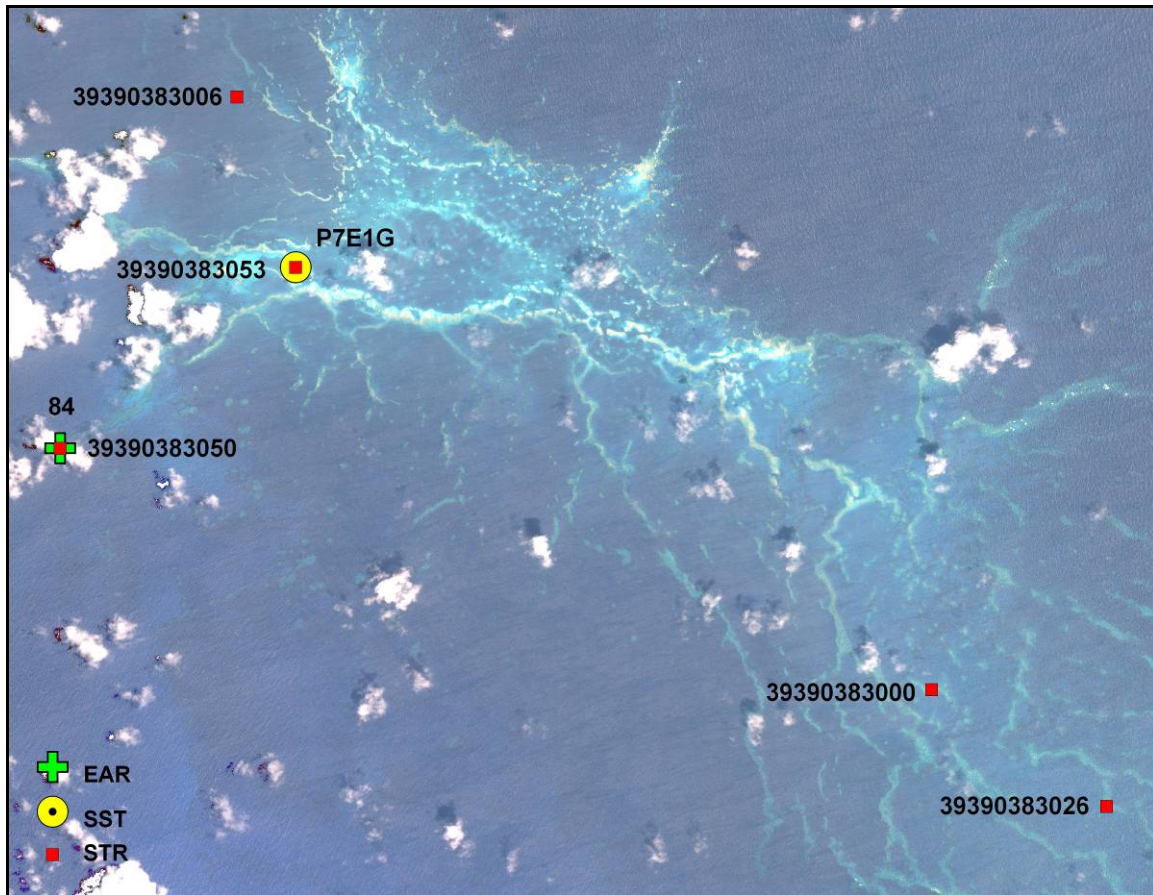


Figure C.1.1.--Moored Oceanographic instrumentation map for Maro Reef. Instruments recovered (top) and instruments deployed (bottom).

Table C.1.1.--Moored oceanographic instrumentation table for Maro Reef.

Instrument	Action	Serial Number	Latitude	Longitude	Data Start	Data End	Depth (m)
EAR	Deployment	84	25.41957	-170.66913		18-SEP-08 20:35	11.58
STR	Deployment	3939038-3050	25.41957	-170.66913		18-SEP-08 20:35	11.58
SST	Deployment	P7E1G	25.44624	-170.63417		18-SEP-08 21:22	0.00
STR	Deployment	3939038-3053	25.44624	-170.63417		18-SEP-08 21:22	14.63
CREWS	Retrieval	280-002					0.00
STR	Retrieval	3930159-0834					0.00
STR	Deployment	3939038-3006	25.47130	-170.64291		19-SEP-08 00:59	14.33
STR	Retrieval	3933179-1146					0.00
STR	Deployment	3939038-3000	25.38410	-170.53972		19-SEP-08 20:40	1.52
STR	Retrieval	3933179-1143	25.38410	-170.53972		19-SEP-08 20:40	1.52
STR	Deployment	3939038-3026	25.36693	-170.51374		19-SEP-08 21:17	4.27

## Preliminary Mooring Results

All four STRs recovered from Maro Reef yielded quality data sets that showed similar time series trends (Fig. C.1.2.). Between September 2006 and September 2008 subsurface water temperatures around Maro fluctuated with seasonal variability typical for these latitudes; lows occurring between January and March ( $\sim 21^{\circ}\text{C}$ ) and highs between August and October ( $\sim 30^{\circ}\text{C}$ ).

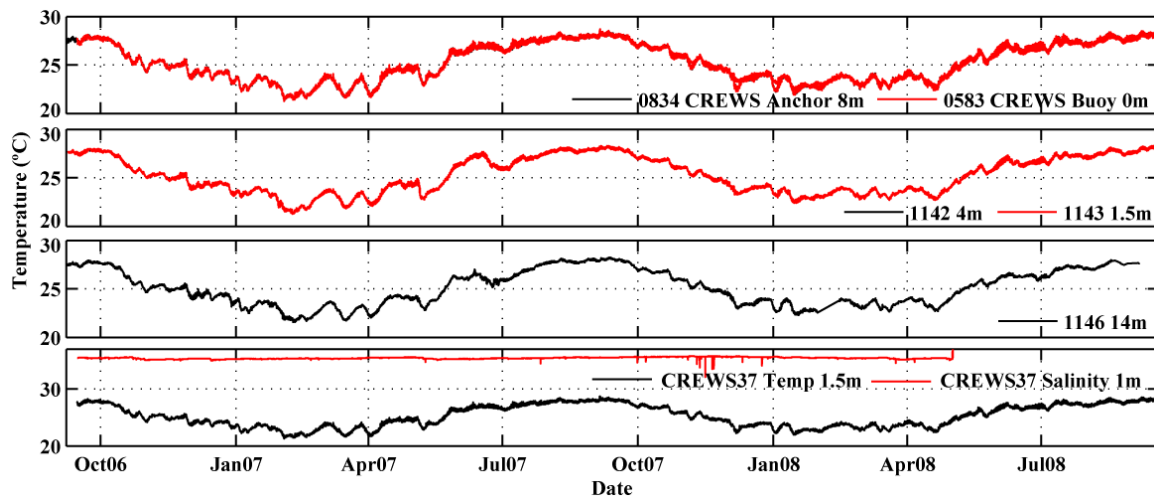


Figure C.1.2.--Temperature data obtained from 4 STR locations. Note that the CREWS anchor STR (0834) and the CREWS buoy STR (0583) overlay each other (top plot), as do STRs 1142 and 1143 (second from top plot), indicating that oceanographically, Maro is a well mixed system.

## Water Quality

Eleven shallow water conductivity, temperature and depth (CTD) casts were conducted at the 30 m bathymetric contour around Maro Reef at approximately 2-nautical mile (nmi) intervals using a Seabird 19+ with additional dissolved oxygen (DO) and transmissometer sensors attached (Fig. C.1.3.). All shallow-water CTD casts were conducted on September 19, 2008. Additionally, 20 “static” (non profiling mode) shallow-water CTD casts were conducted in conjunction with the benthic seawater carbonate chemistry sampling.

Discrete water samples collected concurrently with shallow-water CTD casts at 3 of the shallow-water CTD sites using a daisy chain of Niskin bottles at 1-m, 10-m, 20-m and 30-m depth bins will later be analyzed for nutrient, chlorophyll, and carbonate chemistry (dissolved inorganic carbon (DIC) and total alkalinity ( $A_T$ )) content (carbonate chemistry samples were only collected at the 1-m and 10-m bins). Nutrient, chlorophyll, and carbonate chemistry samples were processed and stored according to protocol and will be sent out for analysis following the cruise. In addition to the standard water sampling that accompanies some of the shallow-water CTD sites, benthic seawater carbonate chemistry samples were collected at 5 sites around Maro Reef over various benthic habitat types



(primarily coral cover). These included five benthic sites in approximately 15 m of water. Each of the benthic sites yielded four carbonate chemistry water samples, two from the bottom, one from the mid depth of the water column and one from just beneath the surface. All benthic carbonate chemistry data will be processed following the cruise.

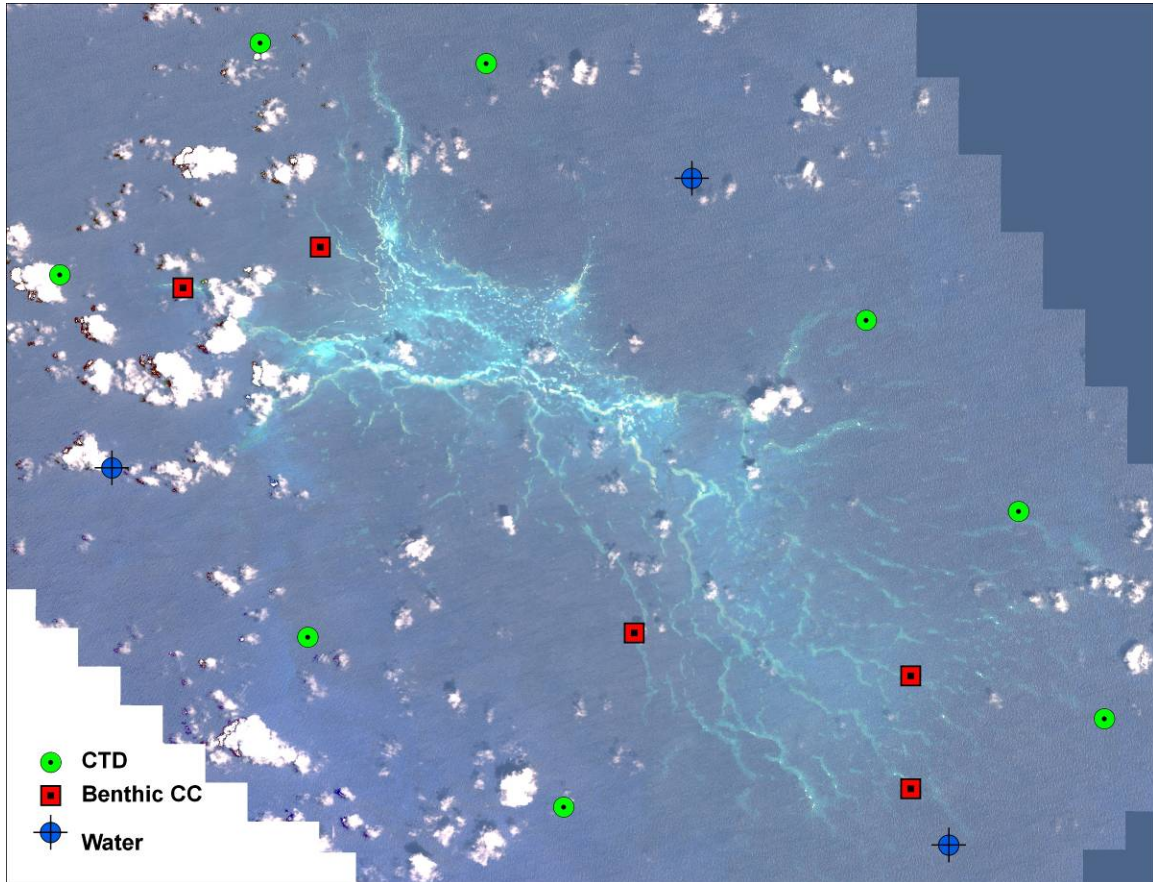


Figure C.1.3.--Shallow-water CTD, water sampling, and benthic carbonate chemistry locations around Maro Reef.

Two permanent shipboard CTD sites near Maro Reef were sampled (Fig. C.1.4.). Each of these casts included a CTD profile to 500 m deep, water samples that will be analyzed for chlorophyll and nutrients at the 3-, 80-, 100-, 125- and 150-m bins, and water samples that will be analyzed for carbonate chemistry (DIC and  $A_T$ ) at the 3 m and 125 m depth bins. The water samples were processed and stored according to protocol and will be sent out for analysis following the cruise.

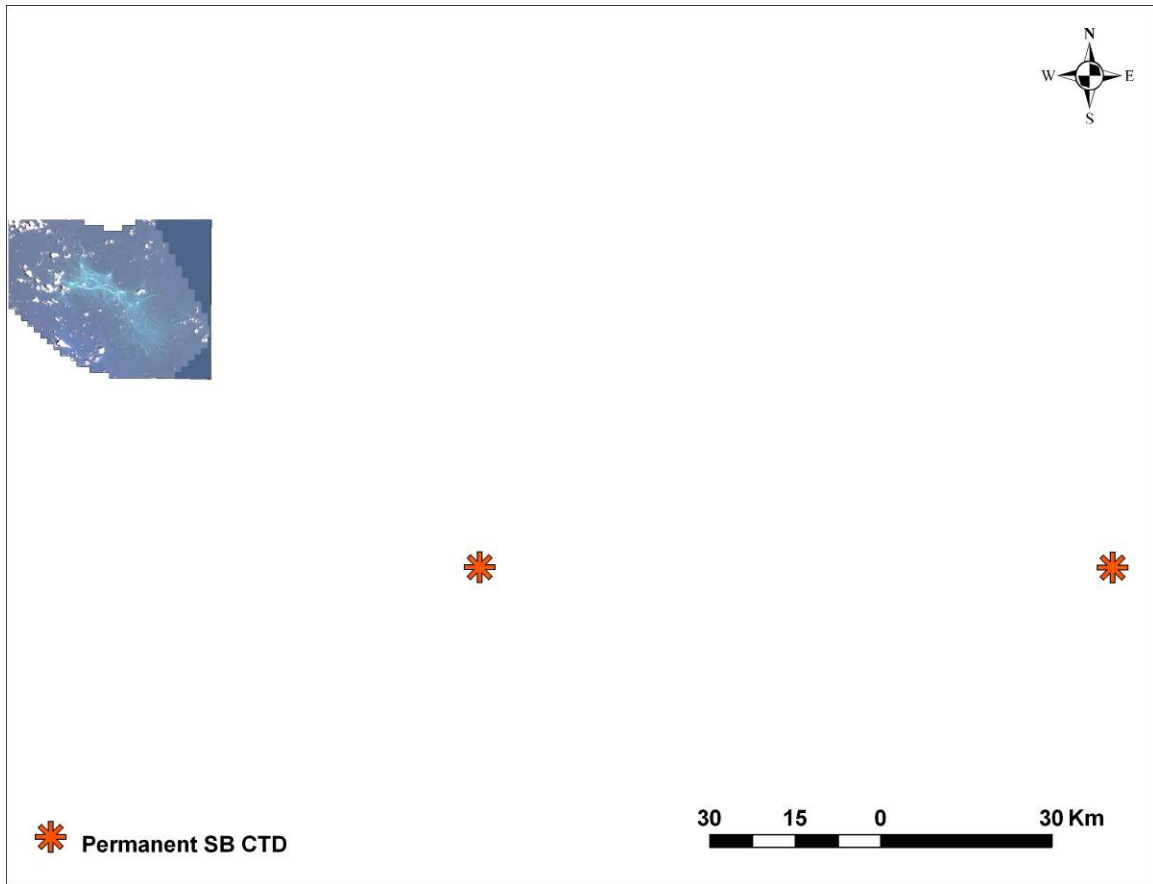


Figure C.1.4.--Permanent shipboard CTD locations near Maro Reef.

## C.2. Rapid Ecological Assessment (REA) Site Descriptions

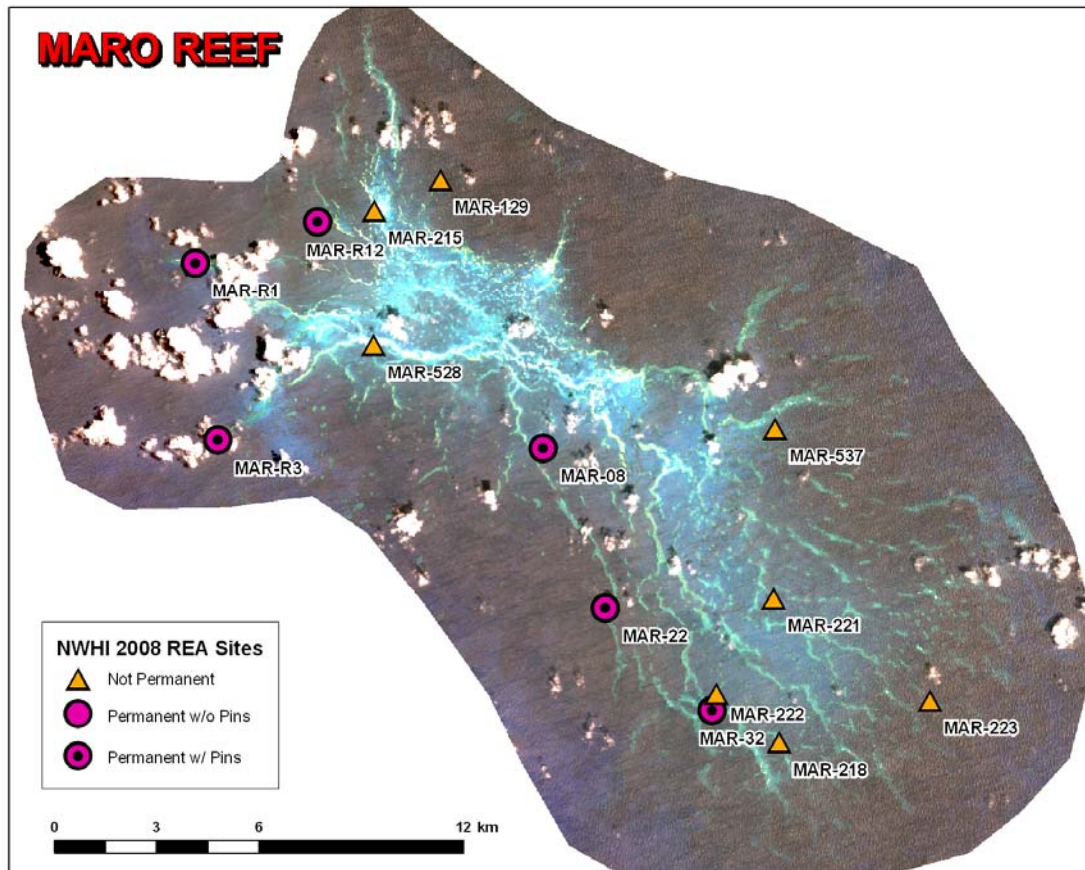


Figure C.2.1.--Sites monitored during HI0809 at Maro Reef.

Table C.2.1.--REA sites visited at Maro Reef during HI0809 (see also Table A.2.2).

MAR-R1	Forereef	8.5–10.5	25°27.678 N	170°40.524 W	18 Sept 2008
MAR-R3	Forereef	12.2–17.4	25°25.131 N	170°40.167 W	18 Sept 2008
MAR-08	Forereef	2.7–7.0	25°24.996 N	170°35.025 W	19 Sept 2008
MAR-R12	Forereef	13.5–15.5	25°28.267 N	170°38.576 W	18 Sept 2008
MAR-22	Forereef	14.3–18	25°22.726 N	170°34.042 W	19 Sept 2008
MAR-32	Forereef	11.0–14.9	25°21.245 N	170°32.358 W	19 Sept 2008
MAR-528	Lagoon	2	25°26.473 N	170°37.706 W	18 Sept 2008
MAR-215	Lagoon	7	25°28.411 N	170°37.698 W	18 Sept 2008
MAR-129	Forereef	13	25°28.854 N	170°36.646 W	18 Sept 2008
MAR-222	Forereef	11	25°21.467 N	170°32.293 W	19 Sept 2008
MAR-221	Forereef	11	25°22.827 N	170°31.388W	19 Sept 2008
MAR-223	Forereef	16	25°21.362 N	170°28.915 W	19 Sept 2008
MAR-218	Forereef	5	25°20.770 N	170°31.300 W	19 Sept 2008
MAR-537	Forereef	15	25°25.273 N	170°31.356 W	19 Sept 2008

#### MAR-R12

September 18, 2008

North spur, ocean fringing reef with high topographical relief. Habitat: forereef. Depth range: 13.5–15.5 m. Used permanent transects (2, 25 m) installed by Greta Aeby in 2005. Compass heading 150°. This high-vertical relief reef site was located adjacent to an expansive sand patch. Turf algae colonizing coral skeletons and *Halimeda opuntia* were the dominant algae found during the line point intercept (LPI) survey. Crustose coralline red algae, non-geniculated crustose coralline red algae, *Halimeda discoidea*, *Bryopsis pennata* and *Caulerpa racemosa* were also found during the LPI survey. *Gibsmithia doytii* and a species of *Nemastoma* were recorded during the Roving Diver survey. It was noted that all of the *Halimeda velasquezii* found was highly epiphytized. Coral cover was 23.6% with *Porites lobata*, *Porites compressa*, and *Montipora patula* being the most common species. This site had high abundances of parrotfishes (*Chlorurus sordidus*, *C. perspicillatus*, *Scarus psitticus*) and Pacific gregories (*Stegastes fasciolatus*), as well as many species of surgeonfish (*Acanthurus triostegus*, *A. blochii*, *A. olivaceus*, *A. leucopareius*, *A. nigrofuscus*, *A. dussumieri*) amongst the tall pinnacles. Off transect sightings included 11 grey reef sharks and moderate groups of Moorish idols (*Zanclus cornutus*).

#### MAR-R1

September 18, 2008

Ocean fringing reef. Habitat: forereef. Depth range: 8.5–10.5 m. Shallow lee of emergent reef crest behind NW spur. Permanent transect stakes were installed at the 1-m, 5-m and 25-m marks of both transects. Compass heading 090°. Algae at this site were relatively low in abundance with turf algae colonizing coral skeletons, crustose coralline red algae and *Halimeda velasquezii* being the dominant species/functional groups of the algal community present. *Halimeda discoidea*, a species of *Laurencia* and *Caulerpa taxifolia* were also recorded during the LPI survey. A species of *Nemastoma*, *Caulerpa racemosa* and cyanophytes were recorded during the Roving Diver survey. It was noted that the majority of the *Halimeda velasquezii* was highly epiphytized. Live coral cover was high (61.6%) composed of mostly *Porites compressa*, *Porites lobata*, *Montipora flabbelata*, and *Montipora capitata*. The site contained moderate diversity and abundance of recorded fish and many interesting off-transect sightings. A school of 12 adult giant trevally (*Caranx ignobilis*) continually swam around the divers, as well as 4 bluefin trevally (*Caranx melampygus*). Also recorded off-transect were an adult green jobfish (*Aprion virescens*) and whitetip shark. At the end of the dive, an adult monk seal appeared and watched the divers from the surface for approximately 10 minutes. The most abundant fishes on transect included Pacific gregories (*Stegastes fasciolatus*), saddle wrasse (*Thalasoma duperrey*) and the Johnston's damsel (*Plectroglyphidodon johnstonianus*).

#### MAR-R3

September 18, 2008

Slope of WNW spur. Habitat: forereef. Depth sloping from 17.4 to 12.2 m progressing along transects. Medium-high topographical relief. Permanent transects used. This deep reef site was located next to a steep slope that dropped to > 40 m of water. The algal

community was dominated by crustose coralline red algae, turf algae colonizing rubble and coral skeletons, and *Halimeda velasquezii*. Cyanophytes and *Bryopsis pennata* were also recorded during the LPI survey. The overall abundance of algae was relatively low compared to the coral cover, and a Roving Diver survey was not conducted due to air limitations. Site was dominated by corals which accounted for 72.8% of the substrate. Dominant corals included *Porites compressa*, *Porites lobata*, *Montipora patula*, and *Montipora capitata*. This site had moderate diversity but relatively low abundances of fish species. The most common species found included the saddle wrasse (*Thalasoma duperrey*), the chocolate dip chromis (*Chromis hanui*) and the goldring surgeonfish (*Ctenochaetus strigosus*). Two black-tip reef sharks were spotted upon reaching the site, as well as one grey reef shark. An eagle ray also visited this site, but was just beyond the transect width.

MAR-22

September 19, 2008

South end of western spur, with medium-high topography, large areas of rubble. Greta's permanent transect relocated and resurveyed. Compass heading 130° (transect 1), 170° (transect 2), with the start of the second transect ~10 m distant from end of first transect. Habitat: forereef. Depth range: 14.3–18 m. Visibility was poor at approximately 30 ft, with lots of particulate matter suspended in water column. This site was at the base of a pinnacle with a benthic community dominated by cyanophytes and turf algae. *Halimeda velasquezii*, *H. discoidea* and *H. opuntia* were also recorded during the LPI survey and were noted to be highly epiphytized. *Gibsmithia hawaiiensis* and a species of *Neomeris* were recorded during the Roving Diver survey. Coral cover was moderately high, 32.4%, consisting of mostly *Porites compressa*, *Porites lobata* (highly fissioned) and *Montipora capitata*. There was a fairly low diversity in fish species, with lots of juvenile fish. Very few large apex predators were seen for such a deep site. Only a few small *Aprion virescens* were seen off transect.

MAR-8

September 19, 2008

Northerly section of western spur. Medium-high topography, including tops, sides, and area in between pinnacles. Greta's permanent transect relocated and resurveyed. Habitat: forereef. Depth range: 2.7–7.0 m. The algal community of this site was dominated by turf colonizing coral skeletons, crustose coralline red algae and *Halimeda velasquezii*. *Dictyosphaeria versluysii*, *Bryopsis pennata*, cyanophytes, a species of *Neostoma*, a species of *Laurencia*, non-geniculated crustose coralline red algae and members of the Gelidiales family were found during the Roving Diver survey. Coral cover was 37.6%. Large mounds of *Porites compressa* which had low percentages of living tissue were common, as were large highly fissioned colonies of encrusting *Porites lobata*. Many juvenile parrotfish were found, as well as a large school of *Acanthurus triostegus*, one large *Caranx ignobilis*, and several small *Aprion virescens*.

MAR-32

September 19, 2008

Sloping side (~ 30°) of mid-section of south spur; moderate topographic relief; Ocean reticulate reef. Habitat: forereef. Depth range: 11–14.9 m. Permanent transect stakes were installed at the 1-m, 5-m and 25-m marks of both transects. Compass heading 270 ° This site was characterized by a rubble/coral slope with an algal community dominated by turf, crustose coralline red algae and cyanophytes. Also recorded during the LPI survey was *Halimeda opuntia* and *H. velasquezii*, both of which were highly epiphytized. *Gibsmithia hawaiiensis* and a species of *Nemastoma* were recorded during the Roving Diver survey. Coral cover at the site was 20.4%. There was a moderate diversity of fish, with many juvenile and adult parrotfish at this site. Large *Aprion virescens* were seen off transect.

Randomly selected Fish Sites:

MAR-528

September 18, 2008

Depth: 2 m

N 25° 26.473 W 170° 37.706

This site is located in the northwestern lagoon of Maro Reef. It was established by the REA fish team as a new sampling location in the shallow lagoon stratum. The site is located within shallow, reticulated portion of reef, surrounded by large sand areas, with substrate composed of coral rubble and small colonies of *Montipora capitata*. Coral cover was low, of moderate complexity. Large schools of *Acanthurus triostegus* were seen, and two large *Caranx melampygus* were on site.

MAR-215

September 18, 2008

N 25° 28.411 W 170° 37.698

Depth: 8 m

This site is located in the northern lagoon of Maro Reef. It was established by the REA fish team as a new sampling location in the moderate lagoon stratum. The area is characterized by a channelized reef with *Halimeda* sandy substrate with low coral cover of high complexity. Schools of large *Monotaxis grandoculis*, and *Caranx melampygus* were in the area. Many juvenile *Scarus dubius*, *Acanthurus triostegus*, and *Chlorurus perspicillatus* were also seen on transect.

MAR-129

September 18, 2008

N 25° 28.854 W 170° 36.646

Depth: 12 m

This site is located on the northern forereef of Maro Reef. It was established by the REA fish team as a new sampling location in the moderate forereef stratum. The site is located on the side of plateau type structure. Coral cover was moderate; approximately 40%, with high complexity. *Porites compressa* was the dominant coral, and many *Fungia* spp. were seen along the transect. Turf algae was common, as were *Halimeda* spp. Small

*Triaenodon obesus* were observed off transect, along with several adult *Monotaxis grandoculus*, *Caranx melampygus*, *Aprion viescens*, and one *Carchaerhinus amblyrhynchos*.

MAR-221

September 19, 2008

N 25° 22.827 W 170° 31.388

Depth: 8 m

This site is located on the southern forereef of Maro Reef. It was established by the REA fish team as a new sampling location in the moderate forereef stratum. Coral was patchy in mounds and pinnacles with steep walls, with the bottom composed of *Halimeda* sand. *Porites compressa* and *P. lobata* were the dominant corals with 40% live coral cover; *Montipora* spp. and *Pavona duerdeni* were also seen. This site had high complexity with pinnacles, mounds, and ledges. The dominant fish species were the parrotfish *Scarus psittacus*, *Chlorurus perspicillatus*, *S. dubius*, *C. sordidus*, seen as both adults and juveniles. Also seen were two large *Caranx ignobilis* at 120 and 150 cm. Six small *C. melampygus* were seen neaking behind the divers.

MAR-222

September 19, 2008

N 25° 21.467 W 170° 32.293

Depth: 7 m

This site is located on the southern forereef of Maro Reef. It was established by the REA fish team as a new sampling location in the moderate forereef stratum. *Porites compressa* was the dominant coral with field of 30–40% coral cover, and rubble channels. Complexity was moderate with high rugosity in the *P. compressa* field but low rugosity in the rubble channels. The dominant algae were *Halimeda* and turf. *Scarus* spp. were the dominant fish species—*Chlorurus perspicillatus*, *C. sordidus*, and *Scarus dubius*—with abundant adults and juveniles. Other small fish observed included the surgeonfish *Acanthurus nigroris*, *A. nigrofuscus*, *Ctenochaetus striogosus*, and the ubiquitous saddlewrasse, *Thalassoma duperrey*. *Naso unicornis* and *N. lituratus* were present in a large school off transect.

MAR-223

September 18, 2008

N 25° 21.362 W 170° 28.915

Depth: 13 m

This site is located on the southwestern forereef of Maro Reef. It was established by the REA fish team as a new sampling location in the moderate forereef stratum. This site was flat and had low relief and complexity. Dominant corals were *Porites lobata* in the encrusting form at 60 to 70% coral cover, and *Pocilopora meandrina*, scattered throughout; crustose coralline algae was also common. Overall, this site was depauperate; of the fish present, small Acanthurid juveniles were recorded most often. Large fish were seen primarily off transect, including 2 *Aprion virescens*, a 5 ft grey reef shark, and 5 Galapagos sharks in the water column during the safety stop.



MAR-218

September 19, 2008

N 25° 20.770 W 170° 31.300

Depth: 6 m

This site is located on the southern forereef of Maro Reef. It was established by the REA fish team as a new sampling location in the shallow forereef stratum. Coral cover of *Porites lobata* and live *P. meandrina* was moderate (~ 50%), with rubble channels, sand, and dead coral (*P. meandrina*) making up the balance. Complexity was low to moderate. Dominant fish were Scarids (*Chlorurus perspicillatus*, *C. sordidus*, *Scarus dubius*) and Acanthurids (*Acanthurus nigroris*, *A. nigrofuscus*, *A. triostegus*, *Ctenochaetus strigosus*). The saddle wrasse *Thalassoma duperrey* was also frequently seen, as was the damselfish *Stegastes fasciolatus*.

MAR-537

September 19, 2008

N 25° 25.273 W 170° 31.356

Depth: 13 m

This site is located on the eastern forereef of Maro Reef. It was established by the REA fish team as a new sampling location in the moderate forereef stratum. Relief and complexity were high with pinnacles and mounds interspersed among *Halimeda* sand patches. The dominant corals were *Porites compressa* and *P. lobata*, although *Halimeda* spp. covered 50% of the substrate and was growing thickly among the corals. Large fish seen on transect included the parrotfish *Chlorurus perspicillatus*, the surgeonfish *Acanthurus dussumieri*, and the snapper *Aprion virescens*.

### C.3. Benthic Environment

#### C.3.1. Algae

Benthic communities around Maro Reef were dominated by turf and macroalgal functional groups (Table C.3.1.1.). A combined total of 13 species of macroalgae were observed (8 chlorophytes, 1 ochrophytes, 4 rhodophytes) from the 6 sites surveyed (Tables C.3.1.2., C.3.1.3.). Individuals of *Halimeda velasquezii* were the most prevalent species encountered at four of the six sites surveyed, and covered 3.6% to 14% of the substrate across all sites (Table C.3.1.2.). Individuals of *Halimeda opuntia* were the most prevalent species documented at sites MAR-R12 and MAR-32 where they covered 21.2% and 13.2% respectively (Table C.3.1.2.). *H. velasquezii* plants were usually very small, did not form a continuous mat over the sea floor, and were generally highly colonized with epiphytes. *H. opuntia* plants were generally larger than *H. velasquezii* but still did not form continuous mats and were also highly epiphytized. *Bryopsis pennata* was common at site MAR-R12 and covered 9.2% of the substrate (Table C.3.1.2.).



Table C.3.1.1. --Percent cover of algal functional groups at long-term monitoring sites at Maro Reef.

Island	Site	Macroalgae	Turf algae	Coralline red algae (crustose + upright)	Cyanobacteria
Maro Reef	MAR-R1	14.8%	21.2%	0.8%	0.4%
	MAR-R3	8.8%	7.2%	8.8%	0.8%
	MAR-08	14.4%	38.8%	7.6%	-
	MAR-R12	32.4%	30.0%	10.0%	-
	MAR-22	8.4%	45.2%	1.2%	12.4%
	MAR-32	17.2%	45.6%	16.8%	-

Table C.3.1.2.--Percent cover of macroalgal species at long-term monitoring sites at Maro Reef. Sum totals for each row equal the percent cover of macroalgae recorded in Table C.3.1.1.

		Chlorophyta					Ochrophyta	Rhodophyta	
Island	Site	<i>Bryopsis pennata</i>	<i>Caulerpa racemosa</i>	<i>Caulerpa taxifolia</i>	<i>Halimeda discoidea</i>	<i>Halimeda opuntia</i>	<i>Halimeda velasquezii</i>	<i>Lobophora variegata</i>	<i>Laurencia</i> sp.
Maro Reef	MAR-R1	-	-	0.4%	0.4%	-	10.8%	-	3.2%
	MAR-R3	0.8%	-	-	-	-	7.2%	0.8%	-
	MAR-08	0.4%	-	-	-	-	14.0%	-	-
	MAR-R12	9.2%	0.4%	-	1.6%	21.2%	-	-	-
	MAR-22	-	-	-	1.2%	0.8%	6.4%	-	-
	MAR-32	-	-	-	-	13.2%	3.6%	0.4%	-

Table C.3.1.3.--Additional species recorded at each site at Maro Reef during Roving Diver surveys.

Site	<b>Chlorophyta</b>
MAR-R1	<i>Caulerpa racemosa</i>
MAR-08	<i>Dictyosphaeria versluisii</i>
MAR-22	<i>Neomeris</i> sp.
	<b>Rhodophyta</b>
MAR-08	Gelid
MAR-22	<i>Gibsmithia hawaiiensis</i>
MAR-32	
MAR-08	<i>Laurencia</i> sp.
MAR-R1	<i>Nemastoma</i> sp.
MAR-08	
MAR-R12	
MAR-32	

### C.3.2. Corals

#### C.3.2.1 Coral Populations

LPI surveys indicate that coral cover at Maro Reef is moderately high with a mean of  $41.4 \pm 8.7\%$ . Within the six forereef sites visited in 2008, corals of the genus *Porites* were the most abundant consisting of 70.8% of the island wide coral composition (Table C.3.2.1.1.). Large mounding colonies of *Porites* (*evermanni* and *lobata*) and branching colonies of *Porites compressa* were common at all sites, while members of the genus *Montipora* appeared more common at the three northwestern sites (Fig. C.3.2.1.1.). Overall, 21 anthozoan species (20 scleractinian and 1 zoanthid) were enumerated within belt surveys

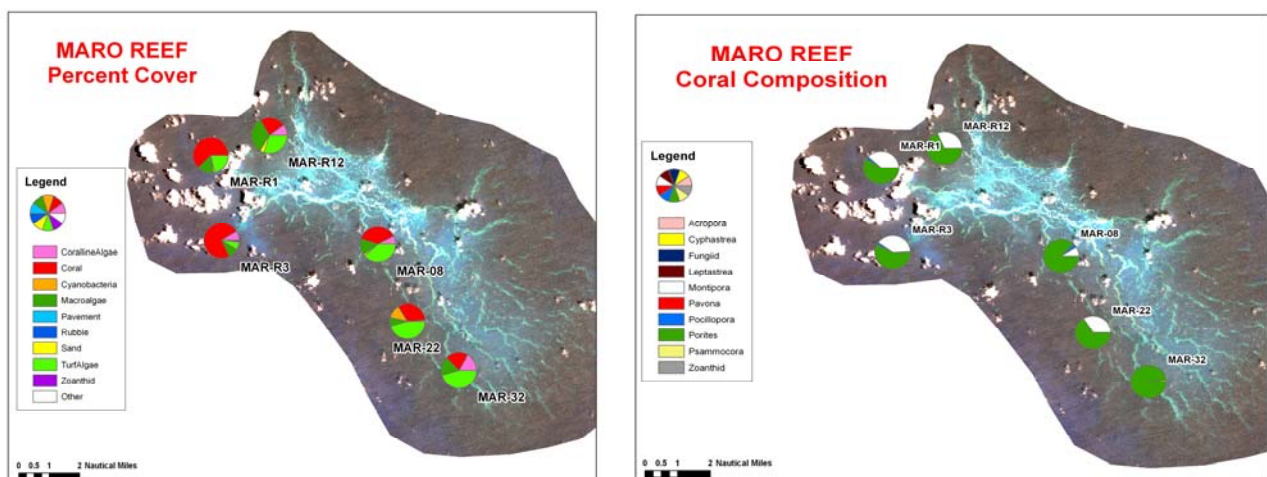


Figure C.3.2.1.1.--Spatial distribution of benthic cover and coral composition for REA sites at Maro in 2008.

Table C.3.2.1.1.--Relative percentage of coral taxon enumerated within belt transects at Maro Reef in 2008.

Taxon Name	Percent	Taxon Name	Percent
<i>Porites lobata</i>	30.1	<i>Psammocora stellata</i>	0.2
<i>Porites compressa</i>	24.3	<i>Pavona varians</i>	0.1
<i>Porites evermanni</i>	16.4	<i>Acropora humilis</i>	0.1
<i>Montipora capitata</i>	12.9	<i>Pocillopora damicornis</i>	0.0
<i>Montipora patula</i>	8.5	<i>Fungia scutaria</i>	0.0
<i>Montipora flabellata</i>	4.9	<i>Porites brighami</i>	0.0
<i>Pocillopora meandrina</i>	1.2	<i>Palythoa</i> sp.	0.0
<i>Pocillopora ligulata</i>	0.4	<i>Leptastrea purpurea</i>	0.0
<i>Cyphastrea ocellina</i>	0.3	<i>Montipora</i> sp.	0.0
<i>Pavona duerdeni</i>	0.2	<i>Porites</i> sp.	0.0
<i>Pocillopora</i> sp.	0.2		

#### C.3.2.2. Coral Disease

Overall, the coral communities at REA sites in 2008 seem to be recovering from the substantial bleaching observed during September 2004 surveys. Prevalence of bleaching was relatively low overall, with the exception of mild signs of bleaching observed in about a third of the colonies of *Montipora capitata*, *M. patula*, and *Cyphastrea ocellina*. Numerous cases of compromised health states were noted involving algal overgrowth and discoloration, and tissue loss were observed in colonies of the genus *Porites* (Fig. C.3.2.2.1.). Percent of live and dead tissue of 10 genera at Maro Reef in 2008 are presented in Figure C.3.2.2.1.

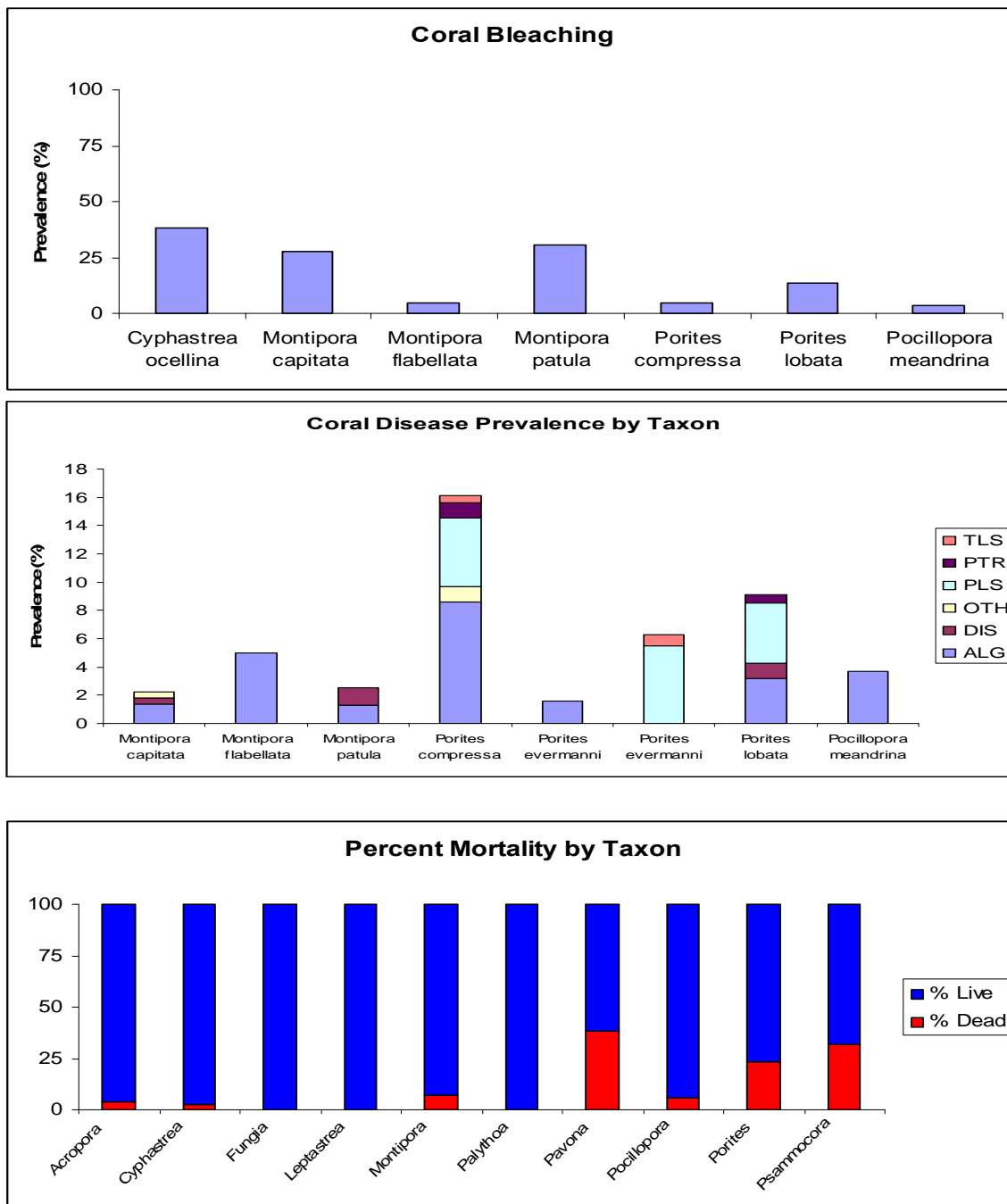


Figure C.3.2.2.1.--Top: Prevalence of bleached colonies for seven taxon at Maro Reef. Middle: Prevalence of coral disease by disease state for eight coral taxon. Bottom: Relative percent of dead surface area for 10 coral genera at Maro Reef.

### C.3.3. Non-coral Invertebrate Surveys

Non-cryptic invertebrates were extremely low around Maro Reef. A total of 151 individuals of benthic invertebrate target species or taxa group were enumerated from 12 belt transects at 6 sites. The sea urchin, *Echinostrephus aciculatus*, was the most abundant benthic invertebrate at Maro. Densities were highest at sites MAR-R3, MAR-

R1, and MAR-22 (0.11, 0.12 and 0.19/m<sup>2</sup>, respectively). Other echinoderms, holothuroids, asteroid, and ophiroids, were exceptionally rare. Only the holothuroids, *Actinopyga obsesa* and *Holothuria whitmaei*, and the ophiroids, *Ophiocoma pica* and *O. erinaceus* were seen. The polychaete, *Loimia medusa*, was common at site MAR-22 with a density of 0.11/m<sup>2</sup>. The lobster, *Panulirus penicillatus*, was common at MAR-08 with a density of 0.07/m<sup>2</sup>. Although not enumerated, the bivalve, *Arca ventricosa*, was widespread throughout sites MAR-32, MAR-R3, and MAR-R12, and the nudibranch, *Pteraeolidia ianthina*, was abundant at MAR-R3. One pearl oyster, *Pinctada margaritifera*, was seen at MAR-08.

#### C.3.3.1. Urchin Measurements

Figure C.3.3.1.1. reveals the average test diameter of urchins from the genus *Echinometra* and *Echinostrephus* encountered at each site. Only sites where  $\geq 5$  measurements were recorded for a species are represented.

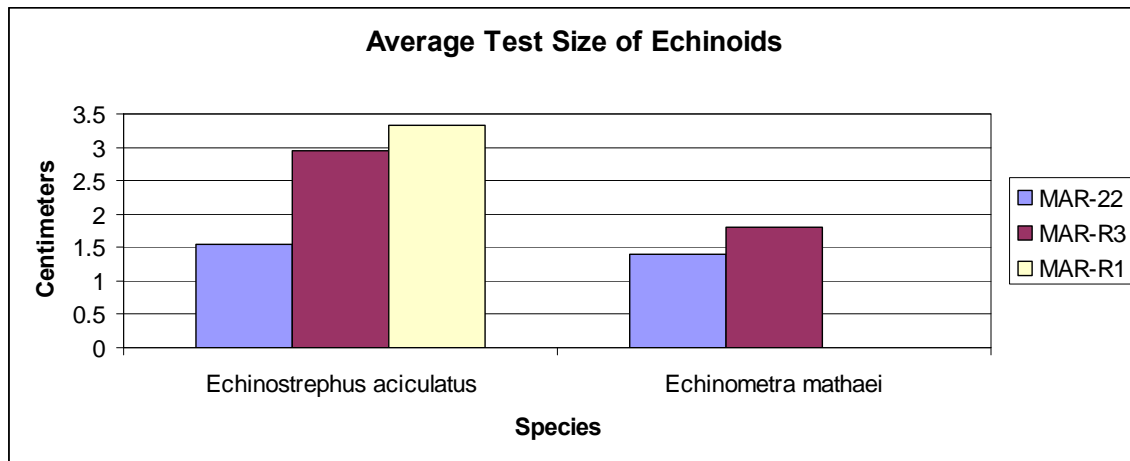


Figure C.3.3.1.1.--Average test diameter of urchins at Maro Reef.

#### C.3.3.2. Autonomous Reef Monitoring Systems (ARMS) Deployment

ARMS were deployed at the following REA sites (Table C.3.3.2.1.) around Maro Reef. Each site contains three ARMS.

Table C.3.3.2.1:--ARMS deployment locations around Maro Reef.

	Latitude	Longitude
MAR-R1	25° 27.678 N	-170° 40.524 W
MAR-R12	25° 28.267 N	-170° 38.593 W
MAR-22	25° 22.714 N	-170° 34.048 W

### C.3.4 Towed-diver Benthic Surveys

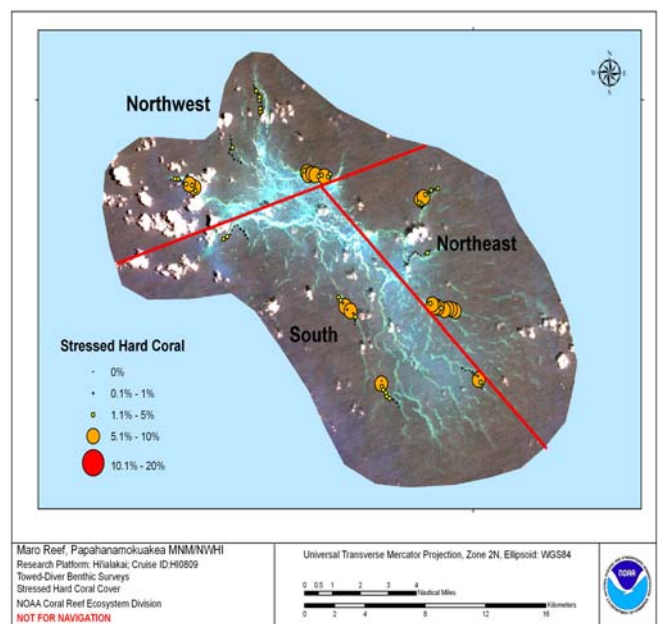
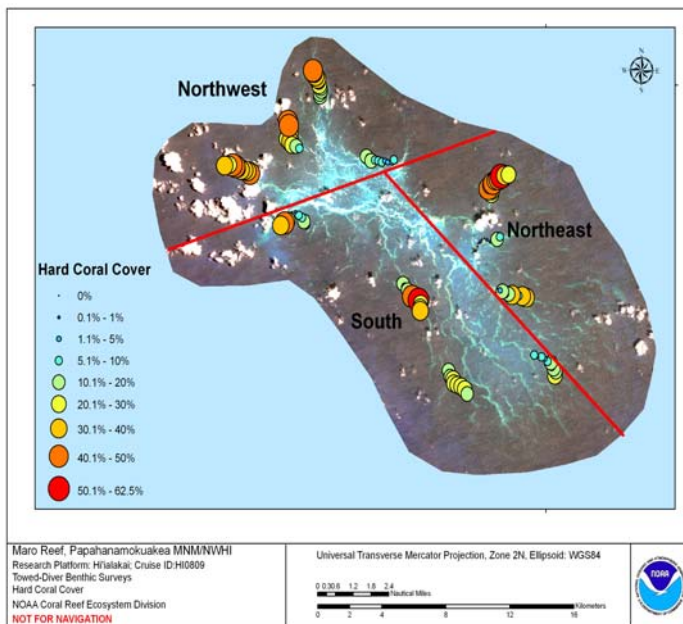
The 11 towed-diver benthic habitat surveys of Maro Reef were all conducted along perimeter, outlying forereef habitat. The overall averages for substrate composition and macroinvertebrate population densities are illustrated in the tables below (Tables C.3.4.1., C.3.4.2.).

Table C.3.4.1.--Overall benthic habitat composition.

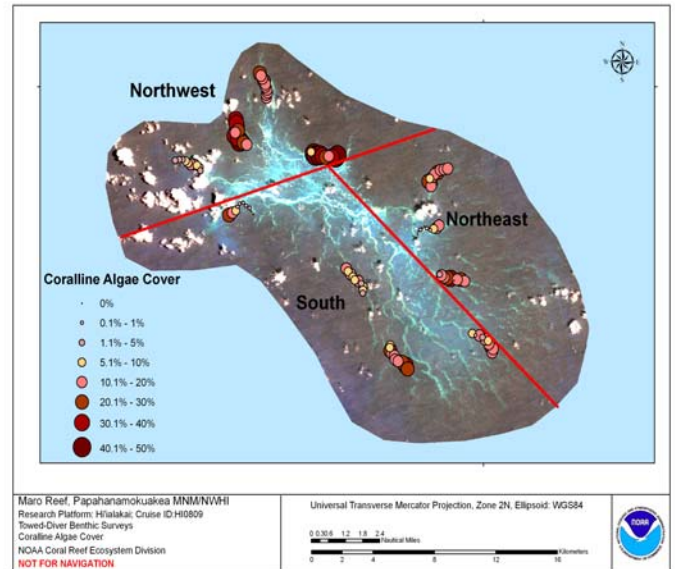
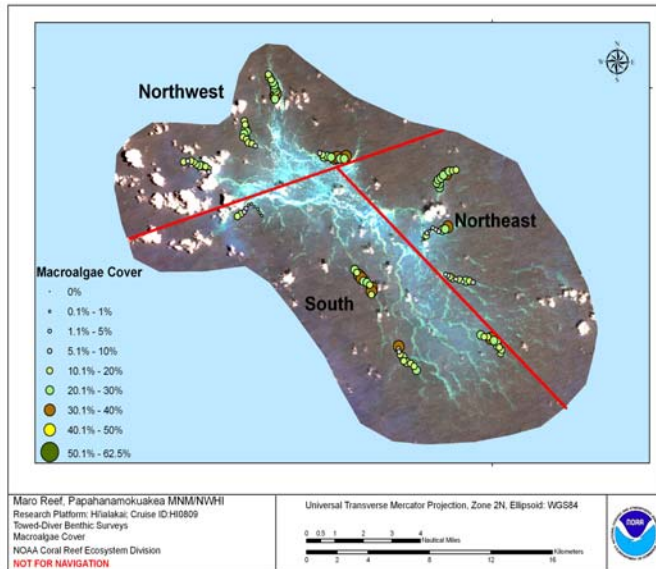
Substrate	Percent cover (%)	Percent cover range (%)
Hard Coral	19.66	0–62.5
Stressed Hard Coral	2.33	0–10
Soft Coral	0.004	0–1
Sand	32.97	0–100
Rubble	7.84	0–50
Macro algae	17.98	0–40
Coralline algae	15.01	0–50

Table C.3.4.2.--Overall macroinvertebrate population densities.

Macroinvertebrate	Density (#/hectare)	Total # observed
<i>Acanthaster Planci</i> (COTS)	0	0
Boring sea urchins	0.023	52
Free-living sea urchins	0.006	13
Sea Cucumbers	0.022	58



Figures C.3.4.1. and C.3.4.2.--Hard coral and stressed coral cover.



Figures C.3.4.3. and C.3.4.4.--Maroalgae and crustose coralline algae cover.

The surveys were further classified according to geographical setting, based on reef exposure to seasonal wind and wave energies at northwestern-, northeastern-, and southern-facing forereef habitats.

Four towed-diver surveys were conducted in the northwest at a mean depth of 13.91 m. They were classified as continuous reef or patch reef of medium complexity, bordering sand flats. The hard corals *Porites compressa*, *Porites lobata*, and *Montipora* sp. dominated these reefs, in order of decreasing dominance, with relatively little stress observed (0–10%). The coral stress that was noted included the paling or bleaching of *Montipora* colonies, paling of *Porites lobata* colonies, and slight paling/bleaching of *Porites compressa* (esp. the colony tips).

Calcareous/coralline algae reached up to 50% cover in places, followed by macroalgae (up to 40%) belonging primarily to *Halimeda* and *Bryopsis*, along with lesser coverage of *Liagora*. Macroinvertebrate counts were generally very low, with no crown-of-thorns starfish COTS observed. The habitat composition and macroinvertebrate population densities for the northwestern reefs of Maro are illustrated in the two following tables (Table C.3.4.3., C.3.4.4).

Table C.3.4.3.--Benthic habitat composition for northwest reefs.

Substrate	Percent cover (%)	Percent cover range (%)
Hard Coral	23.44	0–50
Stressed Hard Coral	2.44	0–10
Sand	28.92	0–75
Rubble	4.71	0–30
Macroalgae	20.75	5.1–40
Coralline algae	22.06	1.1–50

Table C.3.4.4.--Macroinvertebrate population densities for northwest reefs.

Macroinvertebrate	Density (#/hectare)	Total # observed
Boring sea urchins	0.012	13
Free-living sea urchins	0.005	3
Sea Cucumbers	0.044	40

Three towed-diver surveys were conducted in the northeast at a mean depth of 14.42 m. The habitat was classified as continuous reef or patch reef of medium complexity, bordering or surrounded by sand flats. The hard corals *Porites lobata*, *Porites compressa*, and *Montipora* sp. dominated these reefs with relatively little stress observed. The coral stress that was noted included the paling or bleaching of *Montipora* colonies, paling of *Porites lobata* colonies, and slight paling/bleaching of *Porites compressa* (esp. the colony tips). Additional areas of *Porites* (c.f. *eydouxai*) were noted as pale or bleached during a singular survey in the northeast that was deeper (on average) than other surveys completed at Maro Reef. Supplementary photographs were recorded for future georeferencing, review, and comment by coral reef researchers.

Macroalgae of the genera *Halimeda*, *Bryopsis*, and *Liagora* were the second most dominant feature of surveys, followed by calcareous algae (both recording up to 40% cover). Macroinvertebrate counts were very low with no COTS observed. The habitat composition and macroinvertebrate population densities for the northeastern reefs of Maro are illustrated in the two following tables (Tables C.3.4.5., C.3.4.6.).

Table C.3.4.5.--Benthic habitat composition for northeast reefs.

Substrate	Percent cover (%)	Percent cover range (%)
Hard Coral	18.36	0–62.5
Stressed Hard Coral	2.97	0–10
Sand	43.93	0–100
Rubble	2.12	0–30
Macroalgae	15.77	0–40
Coralline algae	11.97	0–40

Table C.3.4.6.--Macroinvertebrate population densities for northeast reefs.

Macroinvertebrate	Density (#/hectare)	Total # observed
Boring sea urchins	0.046	29
Free-living sea urchins	0.001	1
Sea Cucumbers	0.009	6



Four towed-diver surveys were conducted in the south at a mean depth of 11.83 m. The habitat was classified as continuous reef or patch reef of medium complexity, bordering or surrounded by rubble and *Halimeda* sand flats. The hard corals *Porites lobata*, *Porites compressa*, and *Montipora* sp. dominated these reefs with relatively little stress observed. Macroalgae of the genera *Halimeda*, *Bryopsis*, and *Sporochnus* were the second most dominant feature of the area, followed by calcareous algae. Macroinvertebrate counts were very low, with no COTS observed. The habitat composition and macroinvertebrate population densities for the southern reefs of Maro are illustrated in the two following tables (Tables C.3.4.7.,C.3.4.8.).

Table C.3.4.7.--Benthic habitat composition for southern reefs.

Substrate	Percent cover (%)	Percent cover range (%)
Hard Coral	17.19	0–62.5
Stressed Hard Coral	1.60	0–10
Soft Coral	0.01	0–1
Sand	26.07	0–100
Rubble	16.70	0–50
Macro algae	17.45	0–40
Coralline algae	11.01	0–40

Table C.3.4.8. Macroinvertebrate Population Densities for southern reefs

Macroinvertebrate	Density (#/hectare)	Total # observed
Boring sea urchins	0.010	10
Free-living sea urchins	0.011	9
Sea Cucumbers	0.013	12

## C.4 Fish

### C.4.1 REA Fish Surveys

#### *Belt transect data*

During the survey period, 34 belt transect surveys were conducted at 14 sites around Maro Reef. Parrotfishes (Scaridae) were the largest contributor to total biomass with 24.36 kg 100 m<sup>-2</sup>. Jacks (Carangidae) were the second most abundant, followed by surgeons (Acanthuridae) with biomasses of 22.09 and 19.43 kg 100 m<sup>-2</sup>, respectively. (Fig. C.4.1.1.).

#### *Overall observations*

A total of 91 fish species were observed by all divers during the survey period. The average total fish biomass at the sites at Maro during the survey period was 14.516 kg 100 m<sup>-2</sup> for the belt transect surveys (Table C.4.1.1.).

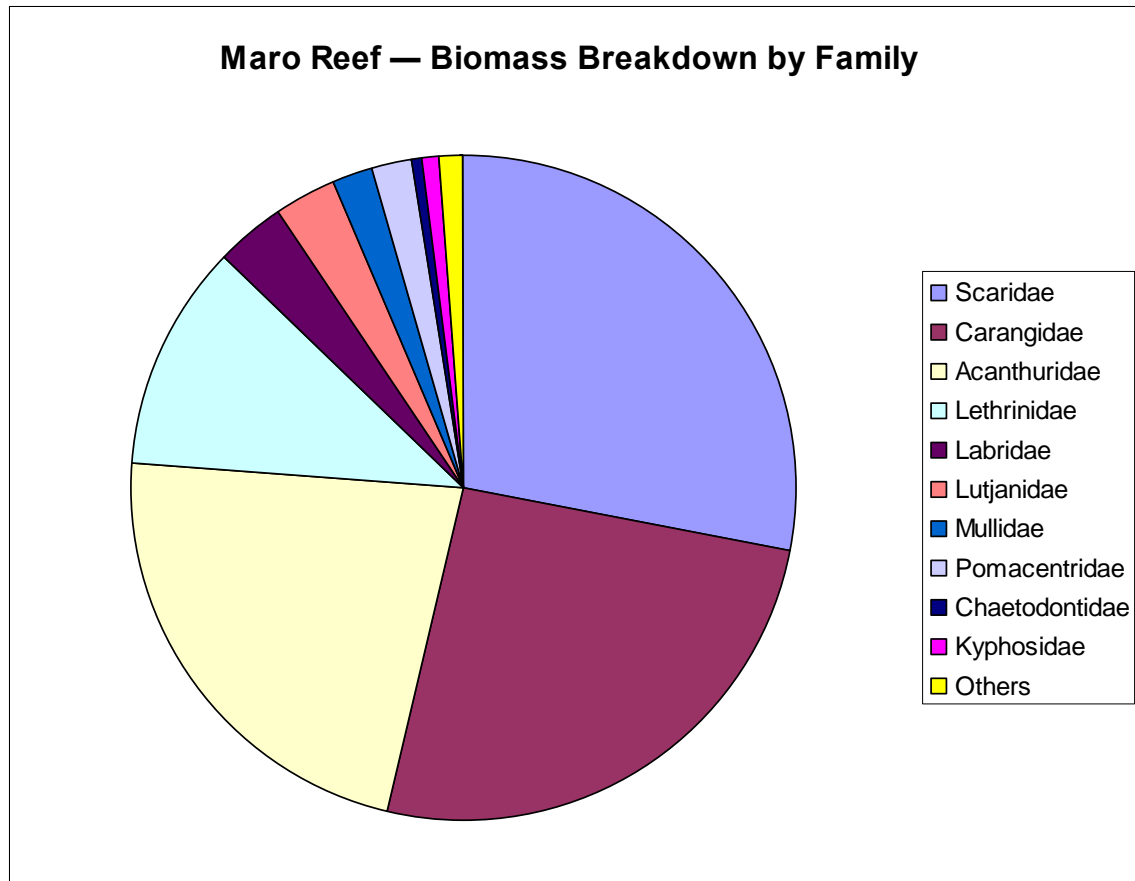


Figure C.4.1.1.--Total fish biomass composition by family.

<b>Table C.4.1.1.--Coral reef fish biomass (kg 100 m<sup>-2</sup>) at sites around Maro Reef.</b>													
Stratum – Depth	Site	Total	Acanth.	Carangid	Chaetod.	Kyphosid	Labrid	Lethrinid	Lutjanid	Mullid	Pomacen.	Scarid	Others
Forereef – Mid	MAR-129	31.90	3.49		0.33		0.18	19.08	0.46	2.05	0.30	5.84	0.18
	MAR-22	5.97	1.42		0.02		0.87	0.05	0.81	0.33	0.39	2.01	0.08
	MAR-221	24.31	1.30	12.68	0.30	1.59	0.71	0.12		1.28	0.14	6.13	0.05
	MAR-222	11.82	2.71		0.01		1.26		1.67	0.27	0.16	5.72	0.02
	MAR-223	2.73	1.07				0.20			0.04	0.06	1.07	0.29
	MAR-32	14.10	4.92		0.19	0.35	0.75	0.08		0.49	0.11	6.64	0.55
	MAR-537	8.77	2.13			0.19	0.71		2.50	0.40	0.36	2.40	0.07
	MAR-R1	13.69	0.16	5.93	0.03		0.38	0.06	0.40	0.06	0.52	2.08	4.05
	MAR-R12	13.34	6.72	0.61	0.09		0.17	0.02	0.92	0.28	0.29	4.17	0.07
	MAR-R3	5.74	1.75		0.21		0.37		0.31	0.14	0.72	1.02	1.21
Forereef – Shallow	MAR-08	18.40	9.93	4.84	0.07	0.29	0.56	0.03	0.48	0.18	0.50	1.38	0.14
	MAR-218	19.05	6.49		0.09		1.58		0.46	0.18	2.84	7.13	0.29
Lagoon – Shallow	MAR-215	24.92	4.44	9.28	0.14		0.49	3.13		0.52		6.85	0.07
	MAR-528	8.48	3.07		0.17	0.57	0.70			0.22	0.15	3.51	0.08
<b>Average</b>		<b>14.516</b>	<b>3.543</b>	<b>6.668</b>	<b>0.137</b>	<b>0.600</b>	<b>0.638</b>	<b>2.822</b>	<b>0.892</b>	<b>0.460</b>	<b>0.502</b>	<b>3.998</b>	<b>0.511</b>

### C.4.2 Towed-diver Fish Surveys

During the 2008 Reef Assessment and Monitoring Program (RAMP) mission, the Coral Reef Ecosystem Division (CRED) towboard team completed 11 surveys at Maro Reef covering 23.4 km (23.4 ha) of ocean floor (Table C.4.2.1.). Mean survey length was 2.1 km with a maximum length of 2.4 km and a minimum of 1.7 km. Mean survey depth was 13.3 m with a maximum depth of 16.5 m and a minimum of 9.5 m. Mean temperature on these surveys was 28.2 °C with a maximum temperature of 28.4 °C and a minimum of 27.9 °C. These values are similar to those recorded in previous survey years (2006: 27.4 °C, 2004: 28.4 °C, 2002: 27.5 °C)

Table C.4.2.1.-- Survey statistics for towboard sampling during HI-08-09.

Island/Atoll/Reef	#	Length (km)					Depth (m)				Temperature (°C)			
		Sum	Mean	Max	Min	SD	Mean	Max	Min	SD	Mean	Max	Min	SD
Kure	14	32	2.3	2.7	1.8	0.02	8.2	16.5	0.9	5.9	26.8	27.3	25.5	0.4
Midway	16	39	2.4	3.2	1.9	0.03	9	16.9	0.7	5.9	27.2	28	26.9	0.3
Pearl & Hermes	27	63	2.3	3.1	1.3	0.03	10.3	16.3	1.2	5.2	27.3	27.9	26.8	0.3
Lisianski	12	24.7	2.1	2.3	1.7	0.02	10	14.2	1.6	3.9	28	28.2	27.8	0.1
Laysan	5	11.5	2.3	2.5	2.1	0.01	11.8	13.6	9.2	1.5	27.9	28	27.8	0.1
Maro Reef	11	23.4	2.1	2.4	1.7	0.01	13.3	16.5	9.5	1.8	28.2	28.4	27.9	0.1
French Frigate	26	56.5	2.2	2.9	1.4	0.03	11.5	17.1	1.8	4.5	27.6	28.3	26.9	0.2

Eighteen species of large-bodied reef fish (> 50 cm TL) from 13 families were encountered at Maro Reef (Table C.4.2.2.). Overall numeric density for this class of reef fishes was 0.023 kg/100 m<sup>2</sup> (2.308 t/ha) with a biomass density of 0.393 kg/100 m<sup>2</sup> (0.039 t/ha). Numeric density values were dominated by *Oplegnathus punctatus* while biomass density was dominated by *Manta birostris*. Carangids (21%), Oplegnathids (18%), Lutjanids (15%), and Acanthurids (13%) contributed most to the overall numeric density (Fig. C.4.2.1.) while Mobulids (76%) and Carangids (7%) contributed most to the overall biomass (Fig. C.4.2.2.).

The geographic distribution of large fish biomass around Maro Reef was fairly even aside from *Manta birostris*, which were encountered on a single tow at Maro Reef (Fig. C.4.2.3.). Other species were encountered at nearly even densities around the reef. On three surveys no individuals greater than 50 cm TL were encountered.

Table C.4.2.2.--Species numeric and biomass density for large-bodied reef fish (> 50 cm TL) observed at Maro Reef during 2008 CRED towed-diver surveys

Species	#	#/100m2	#/ha	Biomass (kg)	kg/100m2	t/ha
Aetobatus_narinari	3	0.001	0.128	10.54702879	0.005	0.000
Aprion_virescens	8	0.003	0.342	24.37972522	0.010	0.001
Aulostomus_chinensis	1	0.000	0.043	0.640747912	0.000	0.000
Bodianus_bilunulatus	1	0.000	0.043	1.825	0.001	0.000
Calotomus_carolinus	1	0.000	0.043	2.93087863	0.001	0.000
Carangoides_ferdau	1	0.000	0.043	2.571799079	0.001	0.000
Caranx_ignobilis	2	0.001	0.085	27.84303355	0.012	0.001
Caranx_lugubris	1	0.000	0.043	4.294346589	0.002	0.000
Caranx_melampygus	5	0.002	0.214	19.3488504	0.008	0.001
Carcharhinus_amblyrhynchus	1	0.000	0.043	42.19742899	0.018	0.002
Cephalopholis_argus	1	0.000	0.043	2.355036083	0.001	0.000
Fistularia_commersonii	1	0.000	0.043	0.075410284	0.000	0.000
Manta_birostris	1	0.000	0.043	703.15	0.300	0.030
Monotaxis_grandoculis	5	0.002	0.214	15.65380806	0.007	0.001
Naso_unicornis	7	0.003	0.299	17.97231634	0.008	0.001
Oplegnathus_punctatus	10	0.004	0.427	25.375	0.011	0.001
Scarus_rubroviolaceus	2	0.001	0.085	5.207948099	0.002	0.000
Seriola_dumerili	3	0.001	0.128	13.34233132	0.006	0.001
Grand Total	54	0.023	2.308	919.711	0.393	0.039
# of Species	18					

Numeric Density Contribution by Family for Large-Bodied Reef Fish (>50cmTL) observed at Maro Reef during 2008 CRED Towed-Diver surveys

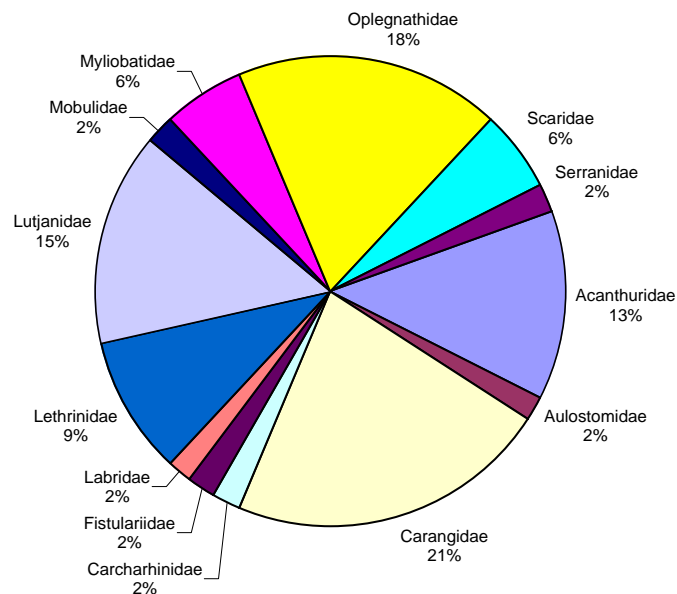


Figure C.4.2.1.--Numeric density by family.

Biomass Density Contribution by Family for Large-Bodied Reef Fish (>50cmTL)  
observed at Maro Reef during 2008 CRED Towed-Diver surveys

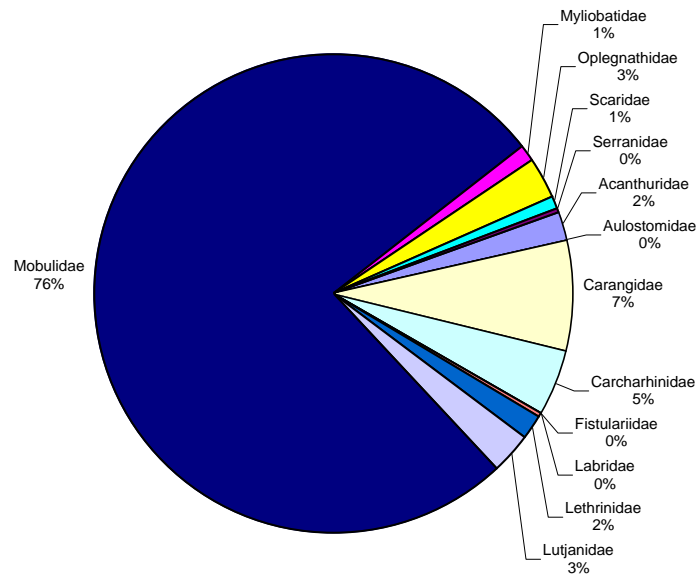


Figure C.4.2.2.--Biomass density by family.

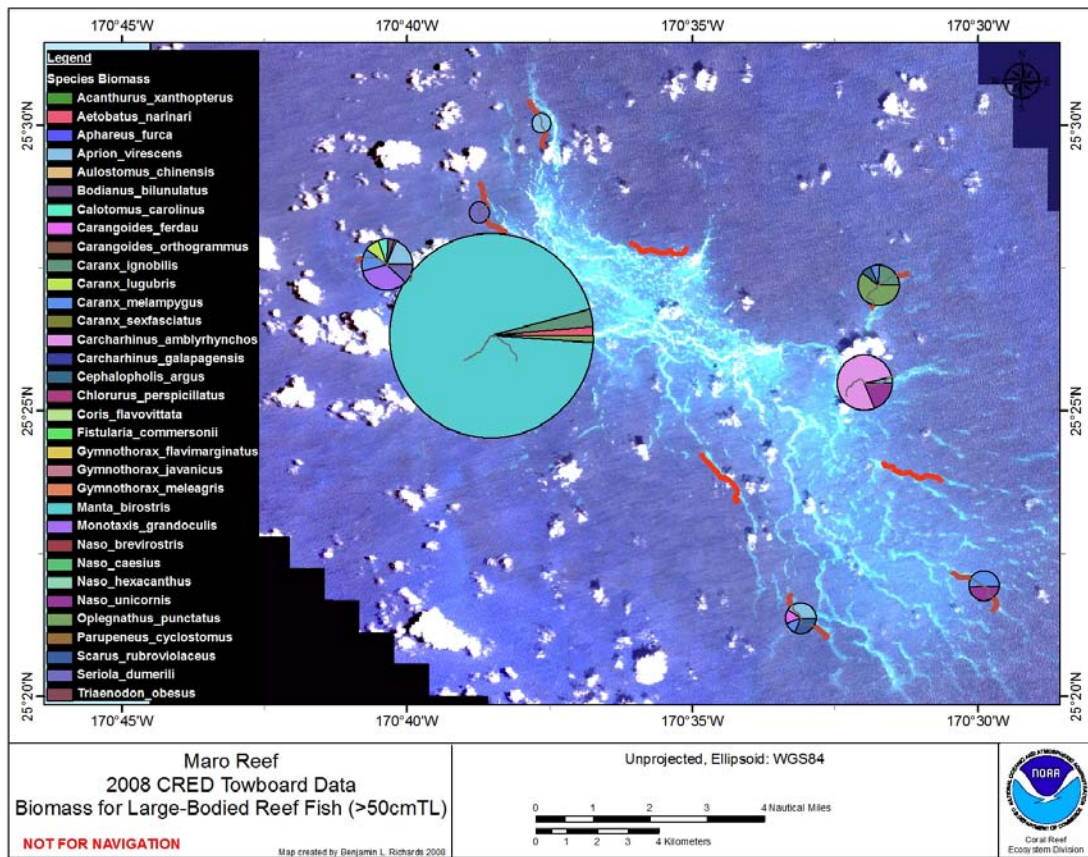


Figure C.4.2.3.--Geographic distribution of biomass around Maro Reef. Each species is represented by a legend color. Diameter of pie chart is proportional to total biomass of all species encountered on the underlying survey.

## Appendix D: Laysan Island

### D.1. Oceanography and Water Quality

Moorings (Fig. D.1.1., Table D.1.1.)

The Coral Reef Ecosystem Division (CRED) oceanography team deployed three subsurface temperature recorder (STR) moorings at Laysan during HI0809, two of which were replacements for long standing time series, and the last was a replacement for the sea surface temperature (SST) anchor STR (Fig. D.1.1.). An SST anchor was removed because the associated buoy broke free and was lost at sea.





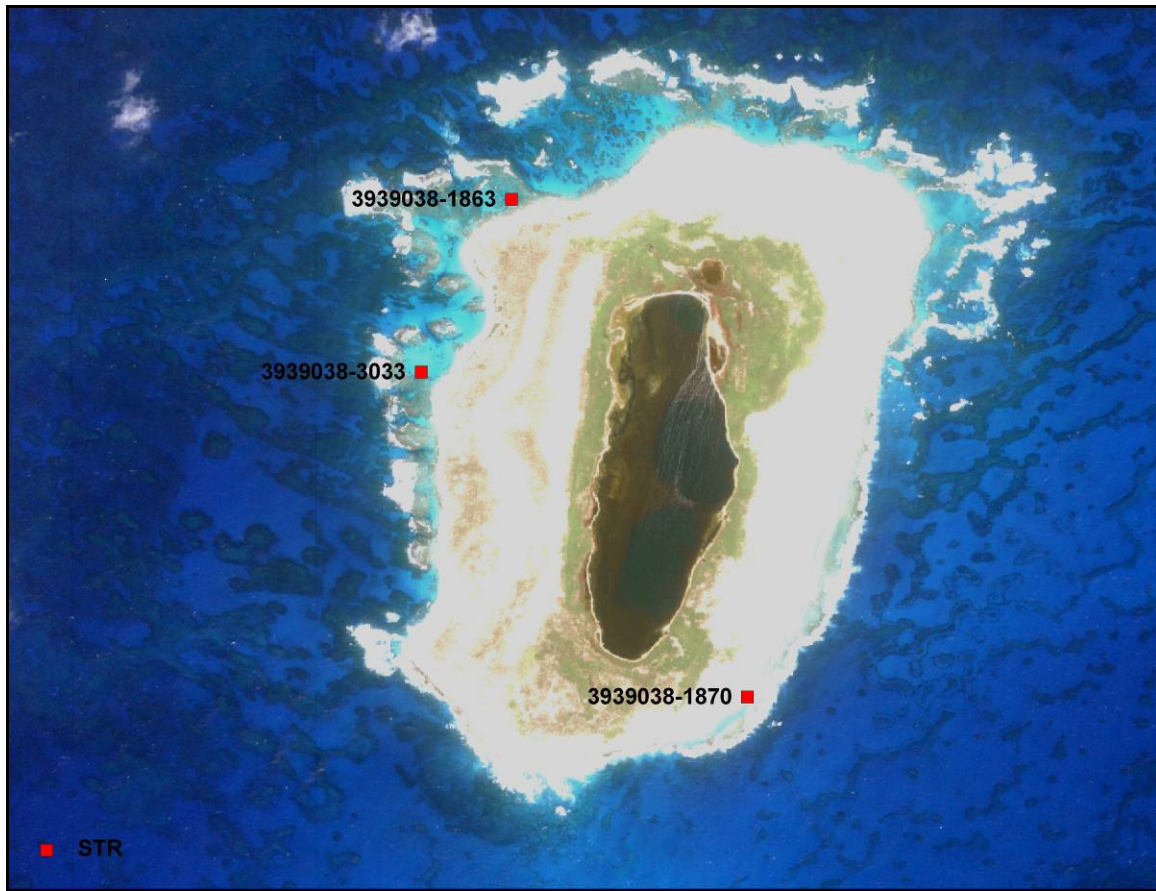


Figure D.1.1.--Moored oceanographic instrumentation maps for Laysan Island. Instruments recovered (top) and instruments deployed (bottom).

Table D.1.1.--Moored oceanographic instrumentation table for Laysan Island.

Instrument	Action	Serial Number	Latitude	Longitude	Data Start	Data End	Depth (m)
STR	Deployment	3939038-3033	25.77244	-171.74263	20-Sep-08	Logging	3.0
STR	Retrieval	3933179-1203	25.77244	-171.74263	10-Sep-06	20-Sep-08	3.0
STR	Deployment	3939038-1870	25.75914	-171.72928	20-Sep-08	Logging	1.2
STR	Retrieval	3933179-1141	25.75914	-171.72928	10-Sep-06	20-Sep-08	1.2
STR	Deployment	3939038-1863	25.77952	-171.73894	20-Sep-08	Logging	1.2
STR	Retrieval	3933179-1370	25.77952	-171.73894	10-Sep-06	11-Apr-07	1.2

### Preliminary Mooring Results

All three STRs recovered from Laysan yielded quality data sets, although one STR had insufficient battery life to last the 2-year deployment period, and showed similar time series trends (Fig. D.1.2.). Between September 2006 and September 2008, subsurface water temperatures around Laysan Island fluctuated with seasonal variability typical for these latitudes; lows occurring between January and March ( $\sim 21^{\circ}\text{C}$ ) and highs between August and October ( $\sim 30^{\circ}\text{C}$ ). Diurnal fluctuations are visibly greater in the shallow waters, especially during the warmer months of August and September where mild weather allows solar heating of the relatively still surface waters.

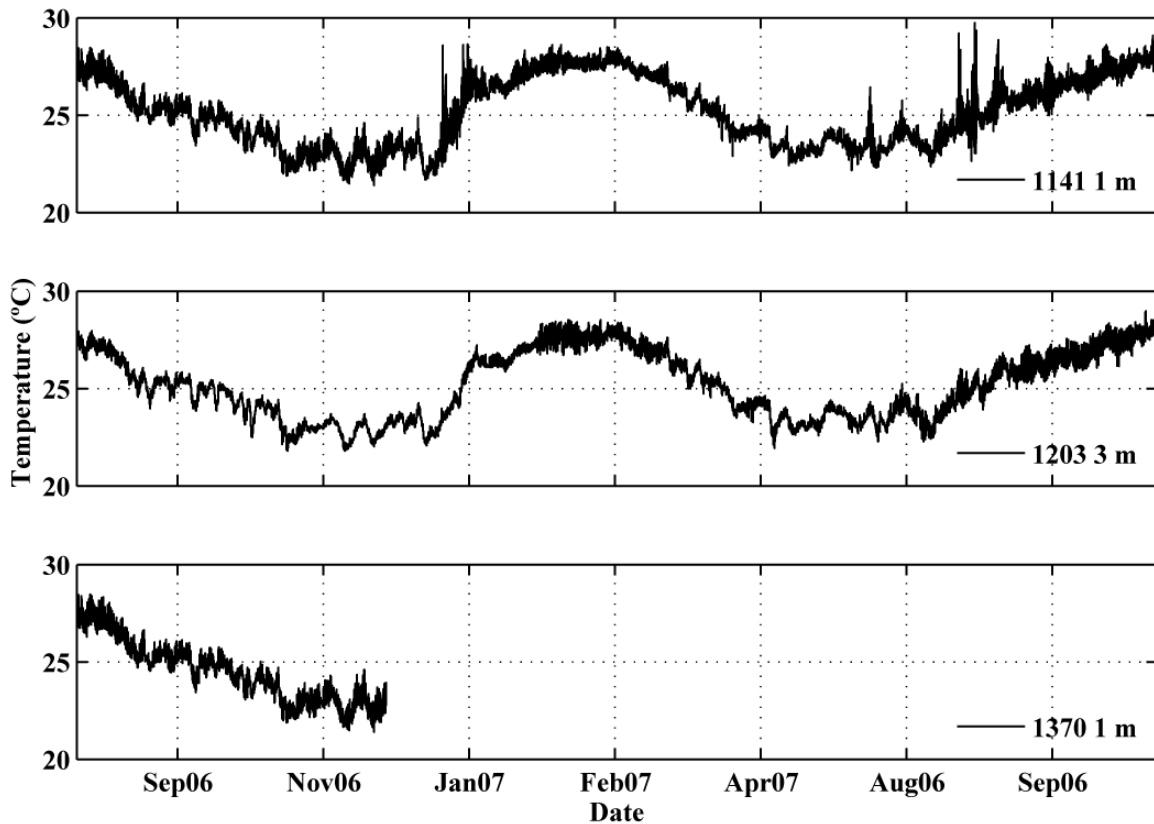


Figure C.1.2.--Temperature data obtained from 3 STR locations at Laysan Island; instrument serial number and deployment depth included in bottom right corner of each time series plot.

### Water Quality:

Seven shallow water conductivity, temperature and depth (CTD) casts, with transmissometer and dissolved oxygen (DO) sensors attached, were conducted at approximately the 20–30-m bathymetric contour around Laysan Island at 2-nautical mile (nmi) intervals (Fig. D.1.3.). Because of the gradual slope of the Laysan forereef and time constraints, some of the CTDs and water samples had to be taken in shallower depths than the typical cast regime. All shallow-water CTD casts were conducted on September 20, 2008.

Discrete water samples collected concurrently with shallow-water CTD casts at 2 of the shallow-water CTD sites using a daisy chain of Niskin bottles at 1-m, 10-m, 20-m and 30-m depth bins will later be analyzed for nutrients and chlorophyll content. The cast on the northern end of the island had samples collected at the 1-m, 10-m, 20-m and 30-m depth bins. The cast on the southern end of the island had samples collected at the 1-m, 10-m, and 20-m depth bins due to the very gradual bathymetric slope on this side of the island. Duplicate samples were taken from the 1-m and 20-m bottles of the second cast for the consistent verification of the analysis methods. Nutrients and samples were processed and stored according to protocol and will be sent out for analysis following the cruise.

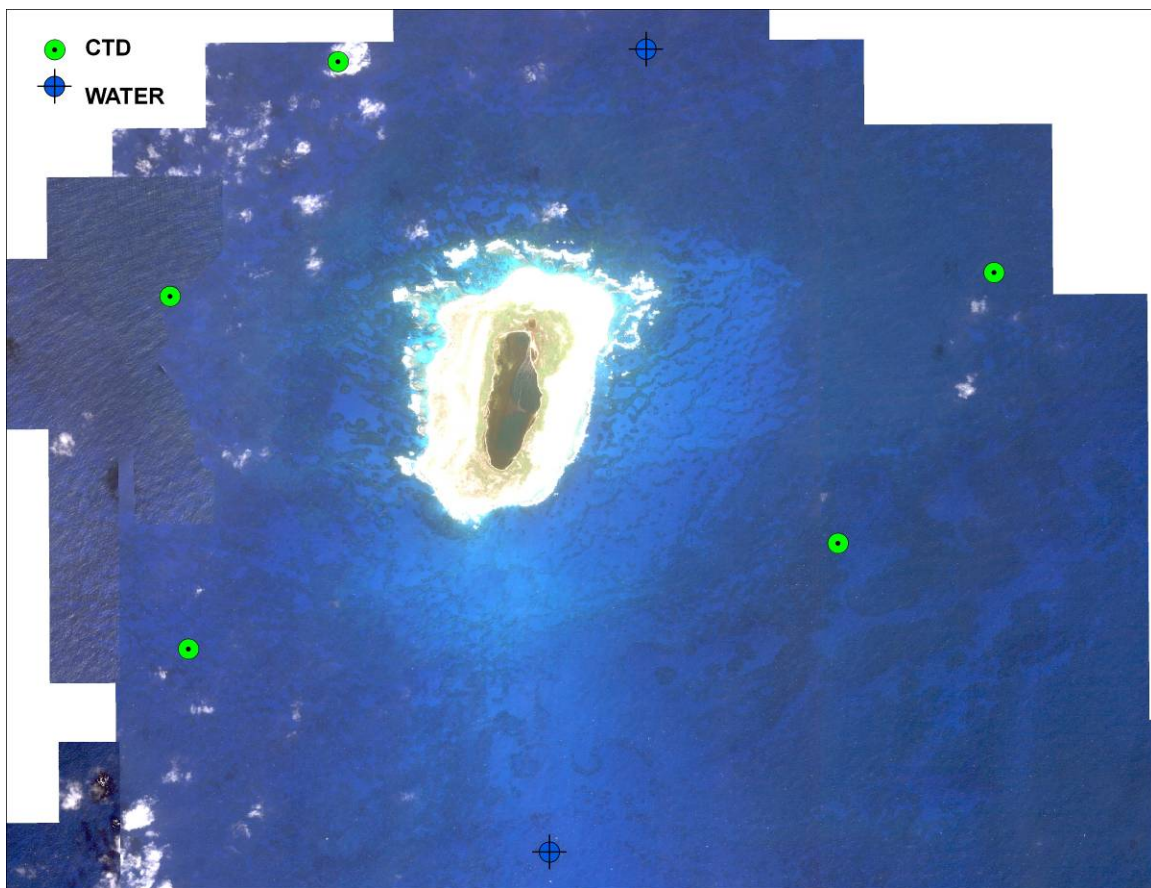


Figure D.1.3.--Shallow-water CTD and water sampling locations around Laysan Island.

One permanent shipboard CTD site near Laysan Island was sampled (Fig. D.1.4.). This cast included a CTD profile to 500 m deep and water samples that will be analyzed for chlorophyll and nutrients at the 3-m, 80-m, 100-m, 125-m and 150-m bins. The water samples were processed and stored according to protocol and will be sent out for analysis following the cruise.

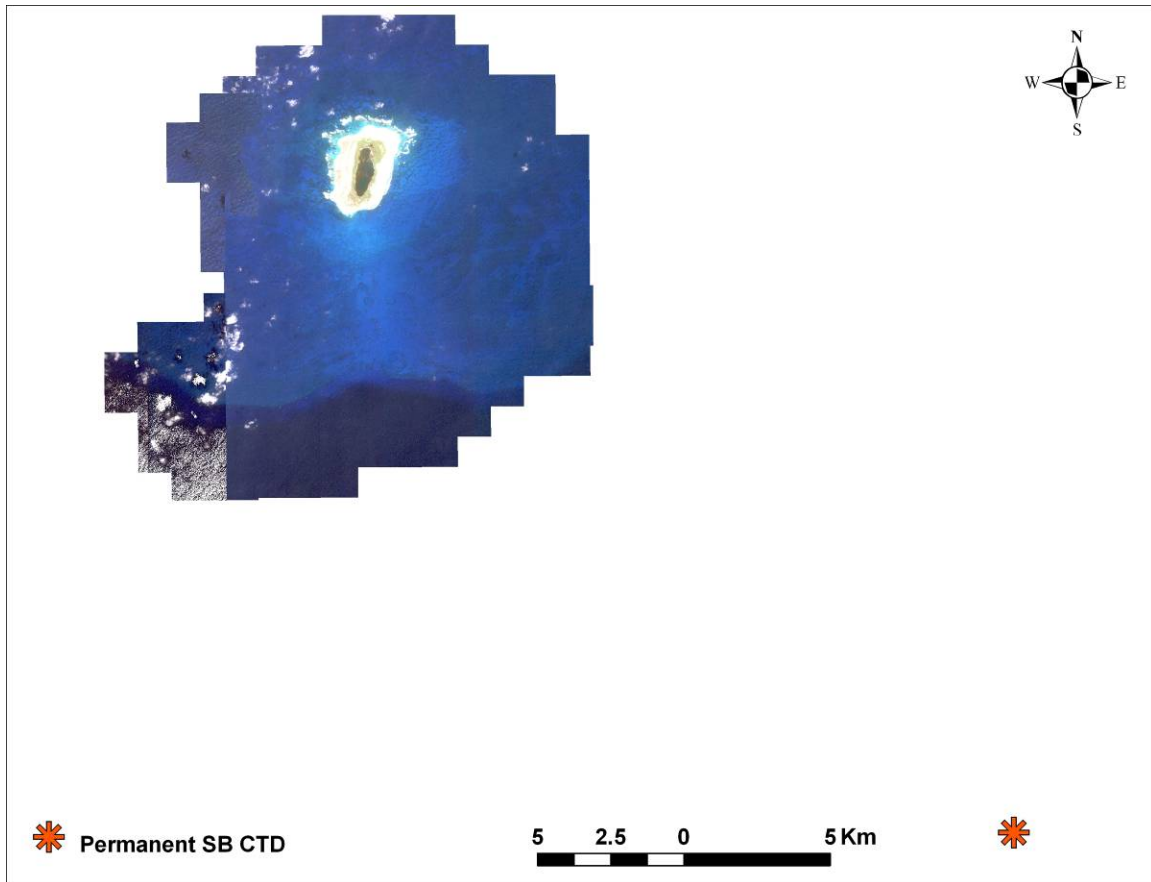


Figure D.1.4.--Permanent shipboard CTD locations near Laysan Island.

#### D.2. Rapid Ecological Assessment (REA) Site Descriptions

Eleven REA sites were visited by a team of up to ten scientists around Laysan Island on September 20, 2008. Eight of those sites were only surveyed by fish scientists. The site locations are plotted in Figure 1, and the survey dates and efforts are listed in Table 1. Individual site descriptions are included for the following discipline communities: coral, coral and coralline disease, macroinvertebrates, algae, and fish.



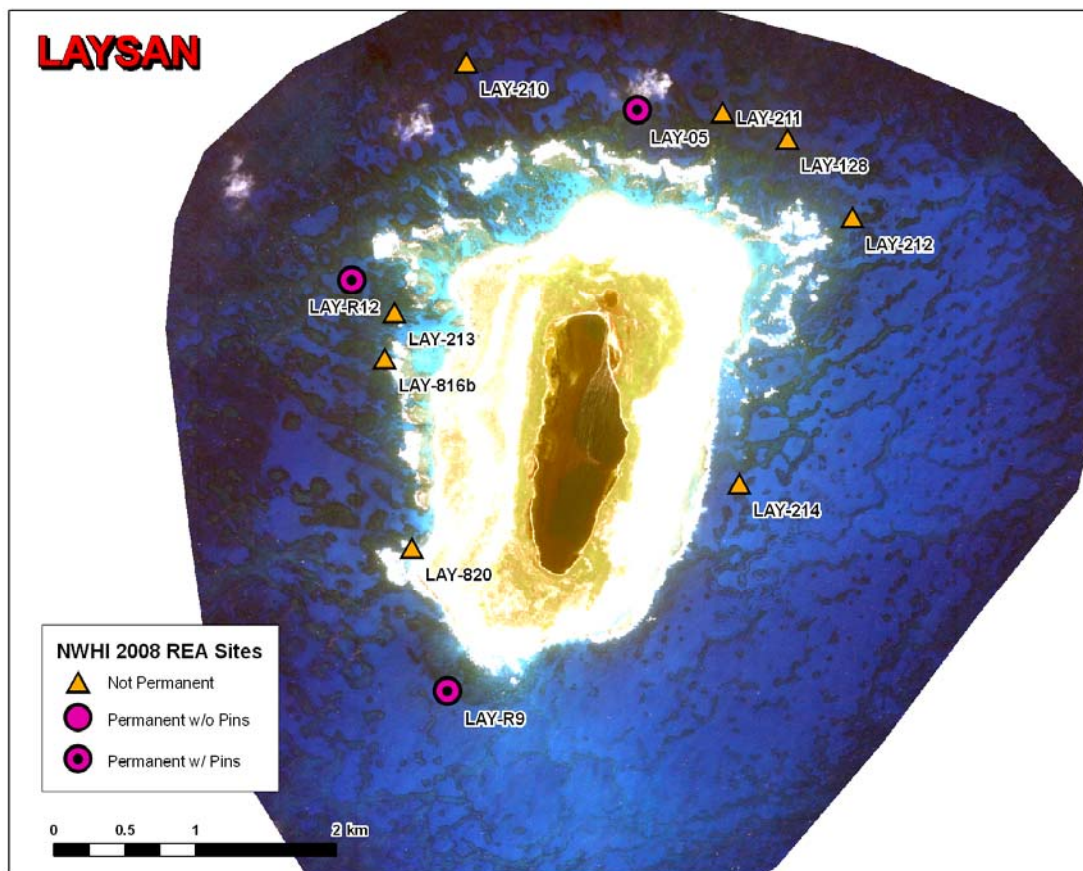


Figure 1.--Laysan Island 2008 REA site locations.

Table 1.--Laysan Island 2008 REA site survey dates, teams present and additional comments (see also TableA.2.2).

Site ID	Date	Teams Present	Comments
LAY-R9	9/20/2008	Coral, Algae, Invertebrate	
LAY-05	9/20/2008	Coral, Algae, Invertebrate	
LAY-R12	9/20/2008	Coral, Algae, Invertebrate	
LAY-820	9/20/2008	Fish	New site – Forereef
LAY-816	9/20/2008	Fish	New site – Forereef
LAY-212	9/20/2008	Fish	New site – Forereef
LAY-211	9/20/2008	Fish	New site – Forereef
LAY-128	9/20/2008	Fish	New site – Forereef
LAY-210	9/20/2008	Fish	New site – Forereef
LAY-214	9/20/2008	Fish	New site – Forereef
LAY-213	9/20/2008	Fish	New site – Forereef

## Site Descriptions:

September 20, 2008

### LAY-R9

*N 25° 45.233', W 171° 44.468'*

Depth range: 8-14 m

Permanent transects. The benthos consisted of mostly rock boulders and scoured pavement outcroppings adjacent to a sandy rubble area. Coral cover was moderately high (24%) composed of highly fissioned, encrusting colonies of *Porites lobata*. Eleven anthozoan species (ten scleractinian and one zoanthid) were observed on transect. Several cases of coralline lethal orange diseases were observed on transect.

This site had a relatively high abundance of algal cover, which was dominated by turf-colonized pavement, *Halimeda velasquezii*, and *Dictyota ceylanica*. Crustose coralline red algae, *Portieria hornemannii*, cyanophytes, and a species of *Laurencia* were also recorded during the LPI survey. *Gibsmithia hawaiiensis*, a species of *Galaxaura*, a species of *Padina*, and *Dasya iridescent* were documented during the Roving Diver survey.

The echinoids, *Echinostrephus aciculatus* and *Echinometra mathaei* were abundant. Few other echinoderms were present with the exception of the ophiuroids, *Ophiocoma pica* and *Ophiocoma erinaceus*.

Low abundances of fish were recorded at this site. Large schools of *Acanthurus triostegus* and *A. leucoparicus* as well as *Naso brevirostris* and *N. unicornis* were observed beyond the transect boundaries. One large trevally (*Caranx ignobilis*) was encountered on transect.

### LAY-05

*N 25° 47.244', W 171° 43.743'*

Depth range: 8–14 m

Permanent transects. The benthos consisted primarily of rock boulders, overhangs, arches, and swim-throughs with very little coral (cover: 7.6%). Scattered *Pocillopora meandrina* colonies with small encrusting *Montipora* colonies were also present. Ten scleractinian species were observed within the survey. Several cases of coralline lethal orange diseases were observed on transect as well as two cases of coralline ring syndrome.

This site had a relatively high abundance of algal cover, which was dominated by crustose coralline red algae, highly epiphytized *Halimeda velasquezii*, and a species of *Laurencia*. Turf-colonized pavement, a species of *Peyssonnelia* and *Dictyota ceylanica* were also recorded during the LPI survey. Non-geniculated crustose coralline red algae, *Dictyota sandvicensis*, *Caulerpa webbiana*, *Lobophora variegata*, *Dictyosphaeria versluysii*, *Dasya iridescent*, cyanophytes and species of *Martensia* and *Jania* were found during the Roving Diver survey.

The echinoids, *Echinostrephus aciculatus* and *Echinometra mathaei* were abundant. The nudibranch, *Pteraeolida ianthina*, and the ophiuroid, *Ophiocoma pica*, were common. Burrows of the shrimp, *Alpheus deuteropus*, within *Porites lobata* were common.

This site has the most diverse fish community of the three REA sites visited at Laysan. While the most abundant fishes were subadult to adult surgeonfishes and wrasses (*Acanthurus nigroris*, *A. nigrofuscus*, *Thalassoma duperrey*) there were multiple sightings both on and off transect of large less commonly seen fishes such as the knifejaw *Oplegnathus punctatus* as well as *Caranx melampygus* and *Aprion virescens*. Off transect recordings included large schools of Kyphosids, as well as schools of *A. leucopariewus* and *A. triostegus*.

### **LAY-R12**

N 25° 46.657', W 171° 44.833'

Depth range: 7–13 m

Permanent transects. The benthos consisted of scoured pavement outcrops with moderate to high algal cover and low coral cover. Coral cover was 12.8% and was dominated by highly fissioned, encrusting colonies of *Porites lobata*. Some remnants of moderately large (50 cm) colonies of *Pavona varians* were noted although only small portions (5–10%) of these colonies remained alive. Ten scleractinian species were observed within the survey. Several cases of coralline lethal orange diseases were observed on transect.

This site had a relatively high abundance of algal cover, which was dominated by turf-colonized pavement, highly epiphytized *Halimeda velasquezii*, and *Microdictyon setchellianum*. Crustose coralline red algae, *H. discoidea*, *Caulerpa webbiana*, *Haloplegma duperreyi*, *Portieria hornemannii*, *Dictyota ceylanica*, non-geniculated crustose coralline red algae, a species of *Peysonnelia*, and *Lobophora variegata* were also recorded during the LPI survey. *Gibsmithia hawaiiensis*, a species of *Galaxaura*, and *Dictyota sandvicensis* were documented during the Roving Diver survey.

The echinods, *Echinostrephus aciculatus* and *Echinometra mathaei* were abundant. *Trapezia* crabs and *Calcinus* hermit crabs were common in *P. meandrina* heads. Burrows of the shrimp, *Alpheus deuteropus*, within *Porites lobata* were common. The ophiuroids, *Ophiocoma pica* and *Ophiocoma erinaceus*, were abundant off-transect in the holes and crevices in the shallower waters off of the second transect.

This site contained predominantly small, substrate-attached fish species such as *Stegastes fasciolatus*, *Thalassoma duperrey* and *Chromis vanderbilti*. Fairly low abundances and diversity of fishes were found on each of the replicates. A few knifejaws (*Oplegnathus punctatus*) were found both on and off transect, while a large school of *Naso unicornis* were found off transect.

**LAY-214**

N 25° 45.947', W 171° 43.354'

Depth: 10 m

This site is located at the eastern forereef of Laysan. It was established by the REA fish team as a new sampling location in the forereef moderate stratum. This low relief, algal-dominated area had very low coral cover; of all corals present, *Porites lobata* was dominant. Small colonies of *Pocillopora* were also found at the site but in very low abundances. Halimeda and turf algae were common on the rock substrate, and small patches of crustose coralline algae were observed as well. Fish diversity here was relatively high, ranging from large *Aprion virescens*, juvenile and adult surgeonfish and goatfish, wrasses to a small cloud of *Chromis vanderbilti*. One friendly *Caranx ignobilis* followed the divers at the end of the dive.

**LAY-212**

N 25° 46.869', W 171° 42.923'

Depth: 10 m

This site is located at the northeastern forereef of Laysan. It was established by the REA fish team as a new sampling location in the forereef moderate stratum. Coral cover here, mainly sparse heads of *Pocillopora meandrina*, was very low. Complexity was high, with caves, ledges, crevices and overhangs providing habitat for a diverse assemblage of fish in this bouldery area. Of great interest was the gang of *Oplegnathus punctatus* darting in and out of their rocky hiding places. Two large *Caranx ignobilis* asserted their presence, and a moderate-sized school of *Monotaxis grandoculis* merged into the transect. The ubiquitous *Thalassoma duperrey* and *Acanthurus nigrofusus* added to the counts, while a few large *Abudefduf abdominalis* checked out the survey divers.

**LAY-128**

N 25° 47.139', W 171° 43.17'

Depth: 12 m

This site was located on the northeastern forereef of Laysan. It was established by the REA fish team as a new sampling location in the forereef moderate stratum. The substrate was flat, gradually sloping to sand. The dominant corals were *Porites lobata* in the encrusting form and *Pocillopora meandrina*. The relief and complexity were low with coral cover from 10 to 15%, with rubble and sandy patches. The substrate was dominated by algae, turf and *Halimeda*. There were large schools of *Acanthurus leucopareus*, and *A. triostegus* off transect with 200 individuals of each species schooling together. There were few large parrotfish at this site and 2 large *Caranx melampygus*.

**LAY-211**

N 25° 47.23', W 171° 43.416'

Depth: 12 m

This site was located on the northeastern forereef of Laysan. It was established by the REA fish team as a new sampling location in the forereef moderate stratum. The substrate was a plateau of large basalt boulders, adjacent to sand flats seaward and a steep wall rising up from a 40-foot depth landward. Complexity and relief were high, however,



coral cover was low at 5% or less, with *Porites lobata* in the encrusting form. Algae and crustose coralline algae dominated the substrate, along with covering dead *Pocillopora meandrina* heads. There was high spp. diversity at this site with several species of goatfishes, (*Parupeneus cyclostomus*, *P. insularis*, *P. multifasciatis*), *Monotaxis grandoculis*, and several species of acanthurids (*Naso literatus*, *N. unicornis*, *N. brevirostris*, *Ctenochaetus strigosus*, *Acanthurus nigrofuscus*). Knifejaws were also seen off transect.

#### **LAY-210**

N 25° 47.402', W 171° 44.395'

Depth: 13 m

This site was located on the northern forereef of Laysan. It was established by the REA fish team as a new sampling location in the forereef moderate stratum. The substrate was flat and algae dominated with low complexity and relief. *Porites lobata* encrusting was the dominant coral with 5% coral cover. There were a lot of dead *Pocillopora* covered with algae. Large *Aprion virescens* and *Monotaxis grandoculis* were located off transect. Two very curious *Caranx ignobilis* followed divers throughout the dive and swam along transect lines. There were moderate schools of *Acanthurus triostegus*, *A. olivaceus*, and *A. leucopareius* off transect.

#### **LAY-213**

N 25° 46.539', W 171° 44.67'

Depth: 4 m

This site is located at the western forereef of Laysan. It was established by the REA fish team as a new sampling location in the forereef shallow stratum. Rugosity at this spur-and-groove area was high, while coral cover was low. *Porites lobata* appeared sporadically; turf algae and *Halimeda* again were common. *Aprion virescens* was the largest fish counted; a large school of the goatfish *Mulloidichthys flavolineatus* was recorded, and an even larger school of *Acanthurus triostegus* was seen grazing off transect.

#### **LAY-816b**

N 25° 46.38', W 171° 44.706'

Depth: 4 m

This site is located at the western forereef of Laysan. It was established by the REA fish team as a new sampling location in the forereef shallow stratum. The site consisted of continuous pavement/rock with moderate to high levels of rugosity. The majority of the site was bare rock with coralline algae with less than 10% coral cover, predominantly of the genus *Pocillopora*. Patches of *Halimeda* and turf algae were common on the rock substrate. Fish diversity and abundance was moderate, with the parrotfishes *Chlorurus perspicillatus* and *C. sordidus* and the wrasse *Thalassoma duperrey* most commonly observed. A few moderate schools of Kyphosids were observed off transect as well as *Caranx melampygus*.

## LAY-820

N 25° 45.726', W 171° 44.604'

Depth: 3 m

This site is located at the southwestern forereef of Laysan. It was established by the REA fish team as a new sampling location in the forereef shallow stratum. Similar to other sites, this site was composed of moderate relief pavement/rock with relatively few reef-forming corals. *Porites lobata* was the most common coral and covered ~ 30% of the transect area. Small colonies of *Pocillopora* were also found at the site but in very low abundances. Approximately 10% of the transect area was composed of small gulches consisting of sand and large rubble. *Halimeda* and turf algae were common on the rock substrate, and small patches of crustose coralline algae were observed as well. Diversity and abundance of fishes were relatively low, with the most abundant species being *Thalassoma duperrey*. Uncommon species recorded on transect included the damselfish *Plectroglyphidodon imparipennis* and the moray eel *Gymnothorax eurostus*. Off transect sightings included a small school of *Caranx ignobilis* and the triggerfish *Rhinecanthus aculeatus*.

### D.3. Benthic Environment

#### D.3.1. Algae

Benthic communities around Laysan Island were dominated by macro-, turf, and crustose coralline red algal functional groups (Table D.3.1.1.). A combined total of 19 species of macroalgae were observed (6 chlorophytes, 3 ochrophytes, 10 rhodophytes) from the 3 sites surveyed (Tables D.3.1.2, D.3.1.3). Individuals of *Halimeda velasquezii* were the most prevalent species encountered, and covered 32% to 44% of the substrate (Table D.3.1.2.). Plants were usually very small, did not form a continuous mat over the sea floor, and generally were moderately colonized with epiphytes. A densely branched, diminutive, deep red species of *Laurencia* was also common at some sites and covered 3% to 11% of the substrate (Table D.3.1.2.). *Dictyota ceylanica* was documented at all three sites surveyed and was a major component of the turf assemblage at LAY-R9. *Microdictyon setchellianum* covered over 6% of the sea floor at LAY-R12 but was a minor component of the algal community at other sites (Table D.3.1.2.).

Table D.3.1.1.--Percent cover of algal functional groups at long-term monitoring sites at Laysan Island.

Island	Site	Macroalgae	Turf algae	Coralline red algae (crustose + upright)	Cyanobacteria
Laysan	LAY-05	54.0%	16.0%	21.2%	-
	LAY-R9	49.2%	14.4%	4.4%	7.2%
	LAY-R12	51.2%	23.2%	11.6%	1.2%

Table D.3.1.2.--Percent cover of macroalgal species at long-term monitoring sites at Laysan Island. Sum totals for each row equal the percent cover of macroalgae recorded in Table D.3.1.1.

		Chlorophyta				Ochrophyta			Rhodophyta			
Island	Site	<i>Caulerpa webbiana</i>	<i>Halimeda discoidea</i>	<i>Halimeda velasquezii</i>	<i>Microdictyon setchellianum</i>	<i>Dictyota ceylanica</i>	<i>Lobophora variegata</i>	<i>Haloplegma dupperreyi</i>	<i>Galaxaura</i> sp.	<i>Laurencia</i> sp.	<i>Peyssonnelia</i> sp.	<i>Portieria hornemannii</i>
Laysan	LAY-05	-	-	44.0%	-	0.4%	0.4%	-	-	8.4%	0.8%	-
	LAY-R9	-	-	32.8%	0.4%	3.6%	-	-	-	11.2%	0.4%	0.8%
	LAY-R12	0.4%	0.4%	37.6%	6.4%	0.4%	0.8%	0.4%	0.4%	2.8%	1.2%	0.4%

Table D.3.1.3.--Additional species recorded at each site at Laysan Island during roving diver surveys.

Site	<b>Chlorophyta</b>
LAY-05	<i>Caulerpa webbiana</i>
LAY-05	<i>Dictyosphaeria versluisii</i>
	<b>Ochrophyta</b>
LAY-R9	<i>Padina</i> sp.
	<b>Rhodophyta</b>
LAY-05	<i>Dasya iridescens</i>
LAY-R9	
LAY-R9	<i>Galaxaura</i> sp.
LAY-R9	<i>Gibsmithia hawaiiensis</i>
LAY-R12	
LAY-05	<i>Jania</i> sp.
LAY-05	<i>Martensia</i> sp.

## D.3.2. Corals

### D.3.2.1 Coral Populations

In 2008, three forereef sites were surveyed for coral composition. Line point intercept (LPI) surveys determined coral cover to be relatively low with a mean of  $11.1 \pm 5.0\%$ . The most abundant genus was *Porites* (86.9%) with the majority (82.7%) of colonies being the large mounding species of *P. lobata* (Table D.3.2.1.1.). Other common corals were from the genus *Pavona* (4.4%) and *Pocillopora* (3.6%). *Porites lobata* was the most common coral found at sites LAY-R12 and LAY-R9 while *Pocillopora meandrina* was more abundant at site LAY-05 (Fig. D.3.2.1.1.). Belt transect surveys showed there to be 13 anthozoan species (12 scleractinian and 1 zoanthid) present at Laysan.

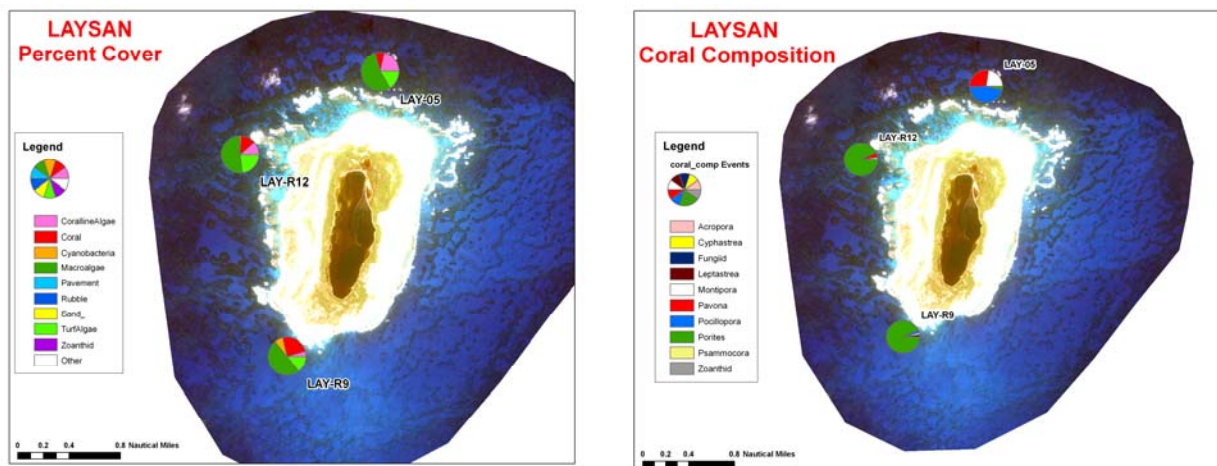


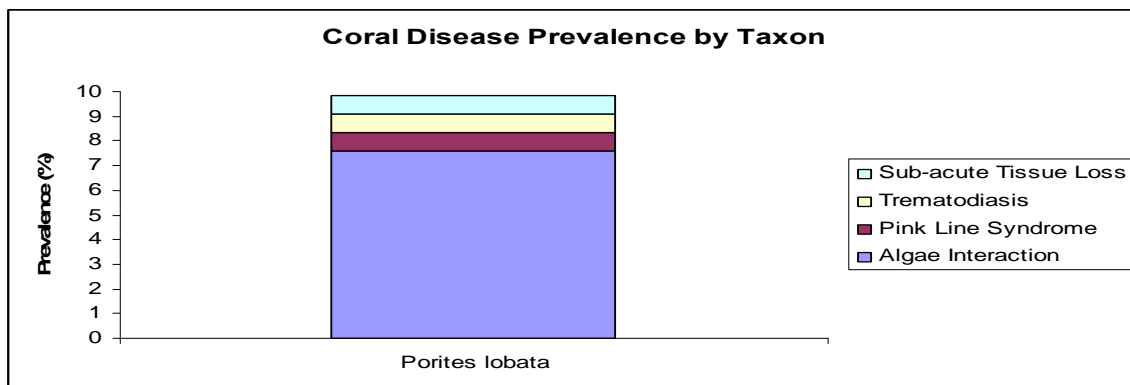
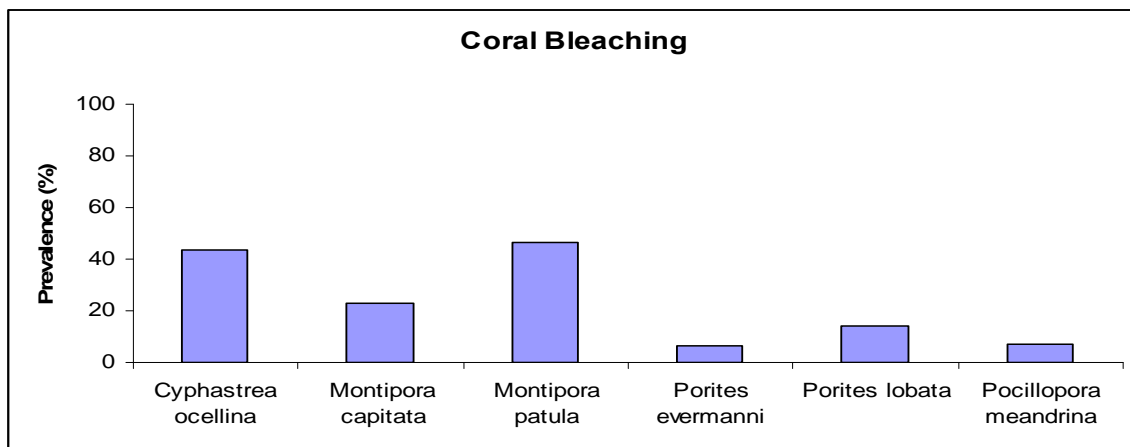
Figure D.3.2.1.1.--Spatial distribution of benthic cover and coral composition for REA sites at Laysan in 2008.

Table D.3.2.1.1.--Relative percentage of coral taxon enumerated within belt transects at Maro Reef in 2008.

Taxon Name	Percent	Taxon Name	Percent
<i>Porites lobata</i>	82.7	<i>Leptastrea purpurea</i>	0.9
<i>Porites evermanni</i>	3.9	<i>Pocillopora</i> sp.	0.7
<i>Pocillopora meandrina</i>	3.6	<i>Porites brighami</i>	0.3
<i>Pavona varians</i>	2.6	<i>Cyphastrea ocellina</i>	0.2
<i>Pavona duerdeni</i>	1.8	<i>Psammocora stellata</i>	0.1
<i>Montipora patula</i>	1.7	<i>Pocillopora ligulata</i>	0.0
<i>Montipora capitata</i>	1.6	<i>Palythoa</i> sp.	0.0

#### D.3.2.2. Coral Disease

Coral communities at 2008 REA sites showed moderate signs of bleaching in *Montipora patula* and *Cyphastrea ocellina* colonies (Fig. D.3.2.2.1.). Numerous cases of comprised health states, including algal interactions, pink-line syndrome, trematodiasis, and subacute tissue loss were observed. Numerous cases of compromised health states were noted involving algal overgrowth, discoloration, and tissue loss in colonies of the genus *Porites* (Fig. D.3.2.2.1.). Percent of live and dead tissue of 10 genera at Maro Reef in 2008 are presented in Figure D.3.2.2.1.



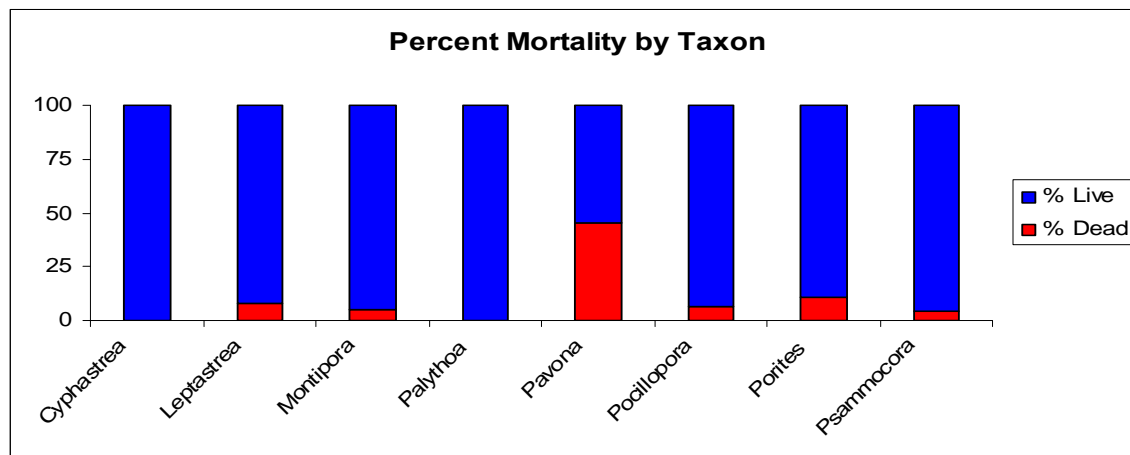


Figure D.3.2.2.1.--Top: Prevalence of bleached colonies for seven taxon at Laysan. Middle: Prevalence of coral disease by disease state for eight coral taxon. Bottom: Relative percent of dead surface area for 10 coral genera at Laysan.

### D.3.3. Non-coral Invertebrate Surveys

A total of 536 individuals of benthic invertebrate target species or taxa group were enumerated from 6 belt transects at 3 sites. Non-cryptic invertebrates were low at Laysan Island with the exception of the echinoids, *Echinostephus aciculatus* and *Echinometra mathaei*. Densities of *Echinostephus aciculatus* were highest at LAY-R9 followed by LAY-05 and LAY-R9 (1.37, 0.9, and 0.3/m<sup>2</sup>, respectively). Densities of *Echinometra mathaei* were highest at LAY-05 followed by LAY-R9 and LAY-R12 (1.14, 0.67, 0.41/m<sup>2</sup>, respectively). With the exception of ophiuroids, other echinoderms, holothuroids and asteroids, were exceptionally rare. Although not quantified, *Ophiocoma pica* and *O. erinaceus* were abundant at all sites and the nudibranch, *Pteraeolidia ianthina*, was abundant at LAY-05. *Trapezia* crabs and *Calcinus* hermit crabs were common at LAY-R12 in *P. meandrina* heads (0.11 and 0.19/ m<sup>2</sup>, respectively). One pearl oyster, *Pinctada margaritifera* was seen at LAY-R9.

#### D.3.3.1. Urchin Measurements

Figure D.3.3.1.1. reveals the average test diameter of urchins from the genus *Echinometra* and *Echinostrephus* encountered at each site. Only sites where  $\geq 5$  measurements were recorded for a species are represented.

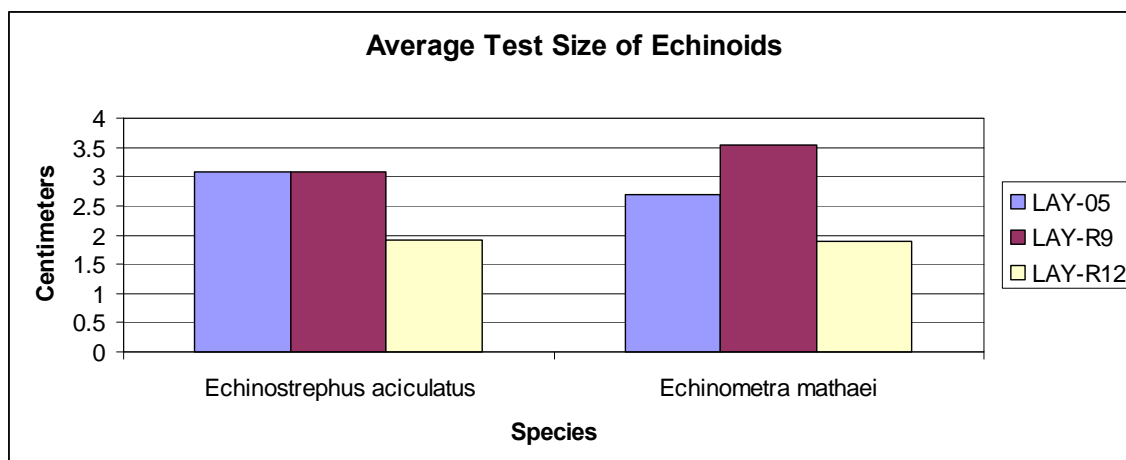


Figure D.3.3.1.1.--Average test diameter of urchins at Laysan Island.

#### D.3.3.2. Autonomous Reef Matrix Systems (ARMS) Deployment

No ARMS were installed around Laysan.

#### D.3.4 Towed-diver Benthic Surveys

The 5 towed-diver benthic habitat surveys of Laysan Island were all conducted along perimeter, outlying forereef habitat. The overall averages for substrate composition and macroinvertebrate population densities are illustrated in the tables below (Table D.3.4.1., D.3.4.2.)

Table D.3.4.1.--Overall benthic habitat composition.

Substrate	Percent cover (%)	Percent cover range (%)
Hard Coral	8.43	0.1–30
Stressed Hard Coral	2.12	0–10
Soft Coral	0.1	0–1
Sand	32.23	10–62.5
Rubble	5.75	0–10
Macroalgae	25.7	10–50
Coralline algae	7.93	0.1–20

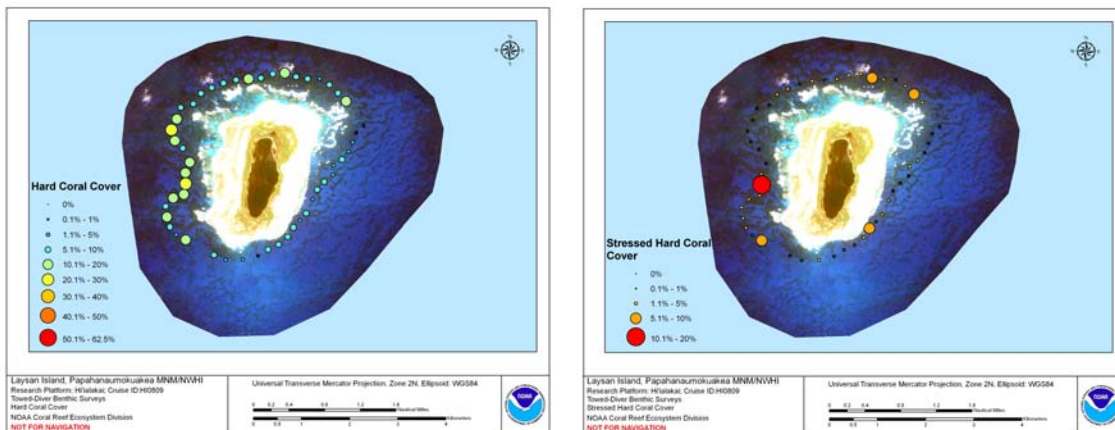
Table D.3.4.2.--Overall macroinvertebrate population densities.

Macroinvertebrate	Density (#/hectare)	Total # observed
<i>Acanthaster Planci</i> (COTS)	0	0
Boring sea urchins	3.03	3448
Free-living sea urchins	0.01	14
Sea cucumbers	0.04	57

The forereef habitat around Laysan was somewhat delineated by region, with pavement, rubble flats, and sand flats in the southeast and southwest; continuous reef/pavement,

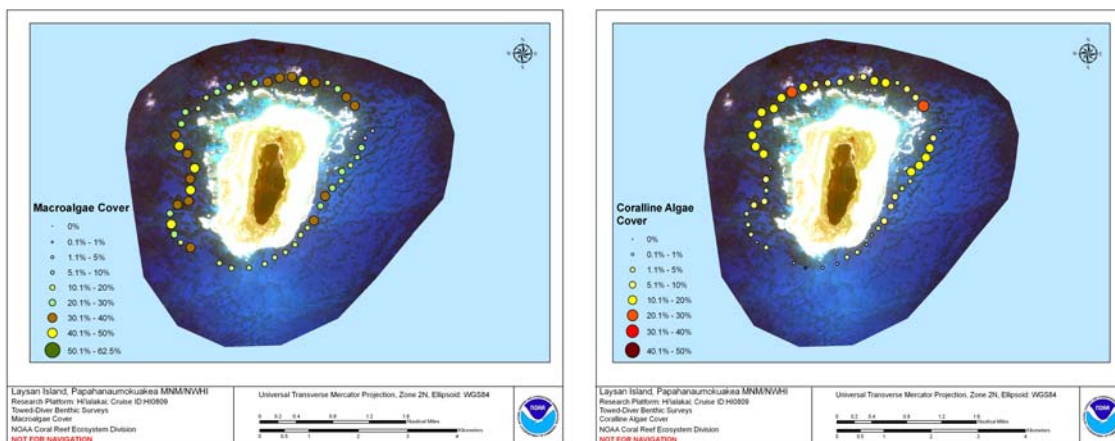
sand flats, and jagged spur-and-groove in the northwest; and pavement/sand flats in the northeast and windward (east) coast.

Hard coral cover was generally low island-wide, averaging around 8.43% and never exceeding 30%. The highest coral cover was generally located along the leeward/western coastline, ending near the northwestern corner. Peak coral cover was noted on either side of the field camp channel entrance, with several segments recording 20.1–30% coral cover. Coral cover on the windward/eastern facing coastline was much lower, generally recorded between 0.1–5%. *Porites lobata*, *Pocillopora* sp., and *Montipora* sp. were noted as prevalent. Low levels of stressed hard coral were recorded as primarily bleaching of smaller colonies belonging to *Montipora* sp.



Figures D.3.4.1. and D.3.4.2.--Hard coral and stressed coral cover.

Macroalgae cover was generally highest along the western and northern forereef areas (average 25.7%, range 10.1–50%). Macroalgae was primarily composed of *Halimeda* and *Liagora* sp. Coralline algae cover was relatively constant along the west, north, and east coasts (10.1–20%, with isolated increases from 20 to 30%), dropping off in the south as sand cover increased.



Figures D.3.4.3. and D.3.4.4.--Macroalgae and coralline algae cover.



Macroinvertebrate counts were generally low for sea cucumbers and free urchins. Boring sea urchins averaged 3.03 /ha<sup>-1</sup>. The highest concentration of sea urchins was found along the west/leeward coast, recording an average of 9.66/ha<sup>-1</sup> for a single survey. No COTS were recorded at Laysan Island.

Finally, four large anchors were also recorded and photographed in the vicinity of the channel entrance. No other marine debris was sighted around the island.

## D.4 Fish

### D.4.1 REA Fish Surveys

#### *Belt transect data*

During the survey period, 25 belt transect surveys were conducted at 11 sites around Laysan. Surgeonfish (Acanthuridae) were the largest contributor to total biomass with 14.04 kg 100 m<sup>-2</sup>. Parrotfish (Scaridae) were the second most abundant, followed closely by jacks (Carangidae) with biomasses of 5.88 and 5.00 kg 100 m<sup>-2</sup>, respectively (Fig. D.4.1.1.).

#### *Overall observations*

A total of 85 fish species were observed during the survey period by all divers. The average total fish biomass at the sites at Laysan during the survey period was 17.87 kg 100 m<sup>-2</sup> for the belt transect surveys (Table D.4.1.1.).

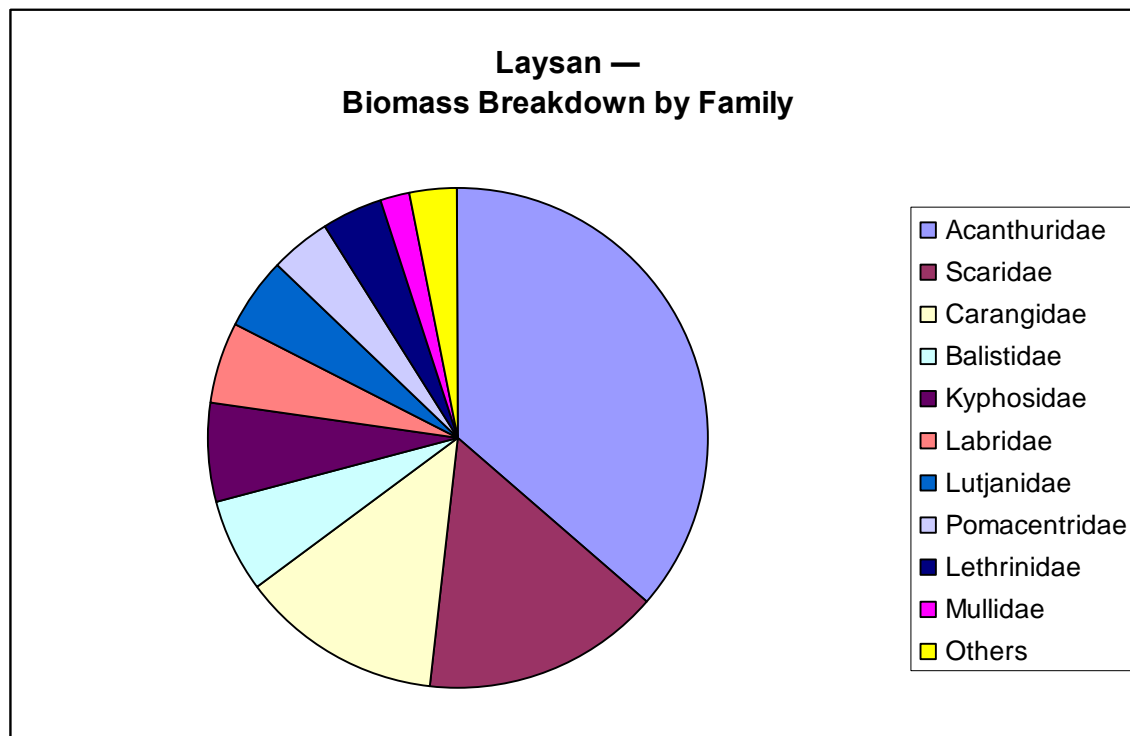


Figure D.4.1.1.--Total fish biomass composition by family.

<b>Table D.4.1.1.--Coral reef fish biomass (kg 100 m<sup>-2</sup>) at sites around Laysan.</b>													
Stratum – Depth	Site	Totals	Acanth.	Carangid	Chaetod.	Kyphosid	Labrid	Lethrinid	Lutjanid	Mullid	Pomacen.	Scarid	Others
Forereef – Mid	LAY-05	24.76	4.51	6.19	0.09	2.29	1.40	2.28	0.11	0.51	0.57	3.58	3.22
	LAY-128	3.99	1.43	1.06	0.21		0.49			0.27	0.18		0.35
	LAY-210	17.53	3.70	8.23	0.02		0.53		4.77	0.09	0.13	0.00	0.06
	LAY-211	22.76	6.12	0.92	0.23	4.90	0.74	0.05	0.34	0.47	4.28	3.10	1.62
	LAY-212	27.01	4.88	4.39	0.07	3.51	0.76	5.66		0.27	3.72	1.01	2.72
	LAY-214	13.92	6.66		0.11	0.03	1.83	0.12	4.10	0.66	0.24	0.09	0.07
	LAY-R12	11.21	2.13		0.03	0.10	0.65	0.30	1.46	0.20	0.21	3.07	3.07
	LAY-R9	8.31	2.92	0.32	0.18	0.12	1.35	0.14	0.84	0.24	0.04	1.64	0.54
Forereef – Shallow	LAY-213	17.01	4.97		0.04	0.92	1.23	0.61	0.46	0.51	0.37	5.41	2.49
	LAY-816	27.88	10.17	4.59	0.04	1.74	1.26	0.64	0.61	0.63	0.59	5.55	2.07
	LAY-820	22.25	14.86	2.51	0.00	0.45	0.88			0.12	0.14	1.99	1.29
<b>Averages</b>		<b>17.87</b>	<b>5.67</b>	<b>3.53</b>	<b>0.09</b>	<b>1.56</b>	<b>1.01</b>	<b>1.22</b>	<b>1.59</b>	<b>0.36</b>	<b>0.95</b>	<b>2.54</b>	<b>1.59</b>

#### D.4.2 Towed-diver Fish Surveys

During the 2008 reef assessment monitoring program (RAMP) mission, the Coral Reef Ecosystem Division (CRED) towboard team completed 5 surveys at Laysan Island covering 11.5 km (11.5 ha) of ocean floor (Table D.4.2.1.). Mean survey length was 2.3 km with a maximum length of 2.5 km and a minimum of 2.1 km. Mean survey depth was 11.8 m with a maximum depth of 13.6 m and a minimum of 9.2 m. Mean temperature on these surveys was 27.9 °C with a maximum temperature of 28.0 °C and a minimum of 27.8 °C. These values are similar to those recorded in previous survey years (2006: 27.2 °C, 2004: 28.1 °C, 2002: 27.5 °C).

Table D.4.2.1.--Survey statistics for towboard sampling during HI-08-09.

Island/Atoll/Reef	#	Length (km)					Depth (m)				Temperature (°C)			
		Sum	Mean	Max	Min	SD	Mean	Max	Min	SD	Mean	Max	Min	SD
Kure	14	32	2.3	2.7	1.8	0.02	8.2	16.5	0.9	5.9	26.8	27.3	25.5	0.4
Midway	16	39	2.4	3.2	1.9	0.03	9	16.9	0.7	5.9	27.2	28	26.9	0.3
Pearl & Hermes	27	63	2.3	3.1	1.3	0.03	10.3	16.3	1.2	5.2	27.3	27.9	26.8	0.3
Lisianski	12	24.7	2.1	2.3	1.7	0.02	10	14.2	1.6	3.9	28	28.2	27.8	0.1
Laysan	5	11.5	2.3	2.5	2.1	0.01	11.8	13.6	9.2	1.5	27.9	28	27.8	0.1
Maro Reef	11	23.4	2.1	2.4	1.7	0.01	13.3	16.5	9.5	1.8	28.2	28.4	27.9	0.1
French Frigate	26	56.5	2.2	2.9	1.4	0.03	11.5	17.1	1.8	4.5	27.6	28.3	26.9	0.2

Eleven species of large-bodied reef fish (> 50 cm TL) were encountered at Laysan Island (Table D.4.2.2.). Overall numeric density for this class of reef fishes was 0.055 kg/100 m<sup>2</sup> (5.524 #/ha) with a biomass density of 0.353 kg/100 m<sup>2</sup> (0.027 t/ha). Numeric density values were dominated by *Chlorurus perspicillatus* while biomass density was dominated by *Caranx ignobilis*. Scarids contributed 24% of the overall numeric density (Fig. D.4.2.1) while Carangids contributed 36% of the overall biomass (Fig. D.4.2.2.).

The geographic distribution of large fish biomass around Laysan was fairly uniform (Fig. D.4.2.3.) with slightly higher levels to the south of the island. *Caranx ignobilis* were encountered frequently but were recorded in the survey space on two surveys on the south and east of the island.

Table D.4.2.2.--Species numeric and biomass density for large-bodied reef fish (> 50 cm TL) observed at Laysan Island during 2008 CRED towed-diver surveys.

Species	#	#/100m <sup>2</sup>	#/ha	Biomass		
				(kg)	kg/100m <sup>2</sup>	t/ha
Acanthurus_xanthopterus	4	0.003	0.345	12.57818385	0.011	0.001
Aetobatus_narinari	1	0.001	0.086	38.19597958	0.033	0.003
Aprion_virescens	4	0.003	0.345	12.72526658	0.011	0.001
Caranx_ignobilis	9	0.008	0.777	116.7222662	0.101	0.010
Caranx_lugubris	1	0.001	0.086	2.48470122	0.002	0.000
Caranx_melampygus	6	0.005	0.518	14.90443438	0.013	0.001
Chlorurus_perspicillatus	16	0.014	1.381	41.64405	0.036	0.004
Gymnothorax_javanicus	2	0.002	0.173	9.720154586	0.008	0.001
Monotaxis_grandoculis	4	0.003	0.345	12.52304644	0.011	0.001
Naso_unicornis	5	0.004	0.432	12.83736881	0.011	0.001
Oplegnathus_punctatus	12	0.010	1.036	35.3346875	0.030	0.003
Grand Total	64	0.055	5.524	309.670	0.267	0.027
# of Species	11					

Numeric Density Contribution by Family for Large-Bodied Reef Fish (>50cmTL) observed at Laysan Island during 2008 CRED Towed-Diver surveys

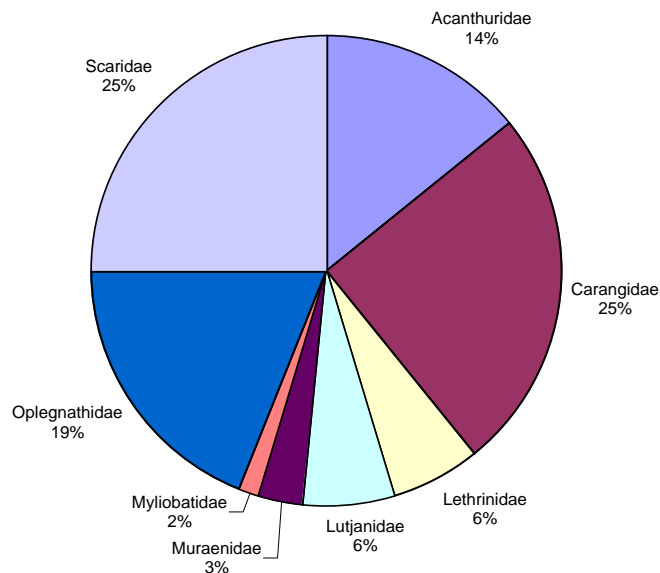


Figure D.4.2.1.--Numeric density by family.

Biomass Density Contribution by Family for Large-Bodied Reef Fish (>50cmTL)  
observed at Laysan Island during 2008 CRED Towed-Diver surveys

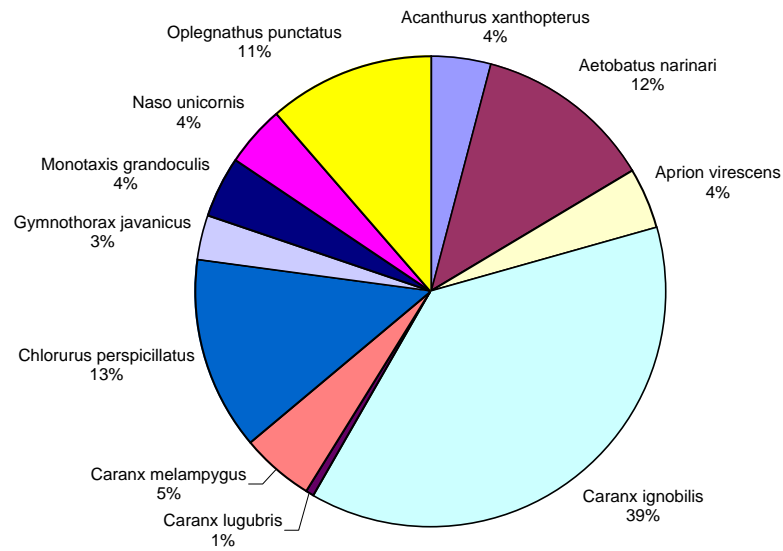


Figure D.4.2.2.--Biomass density by family.

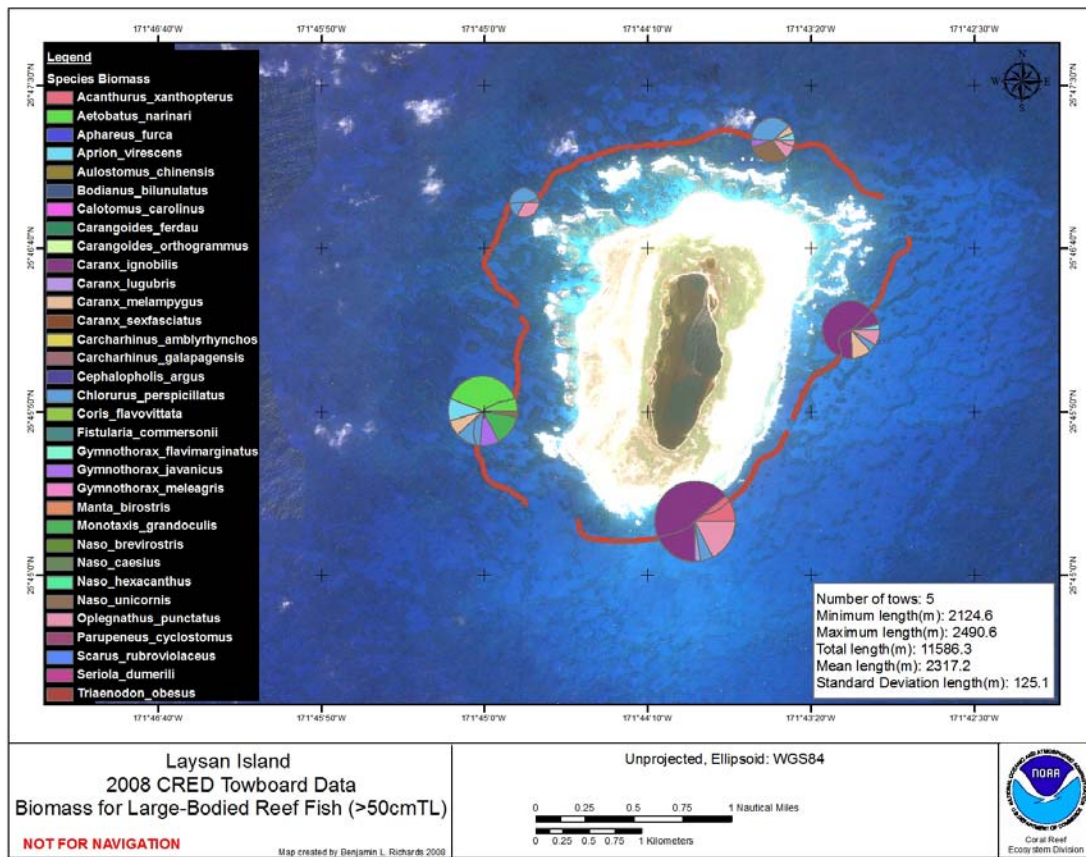


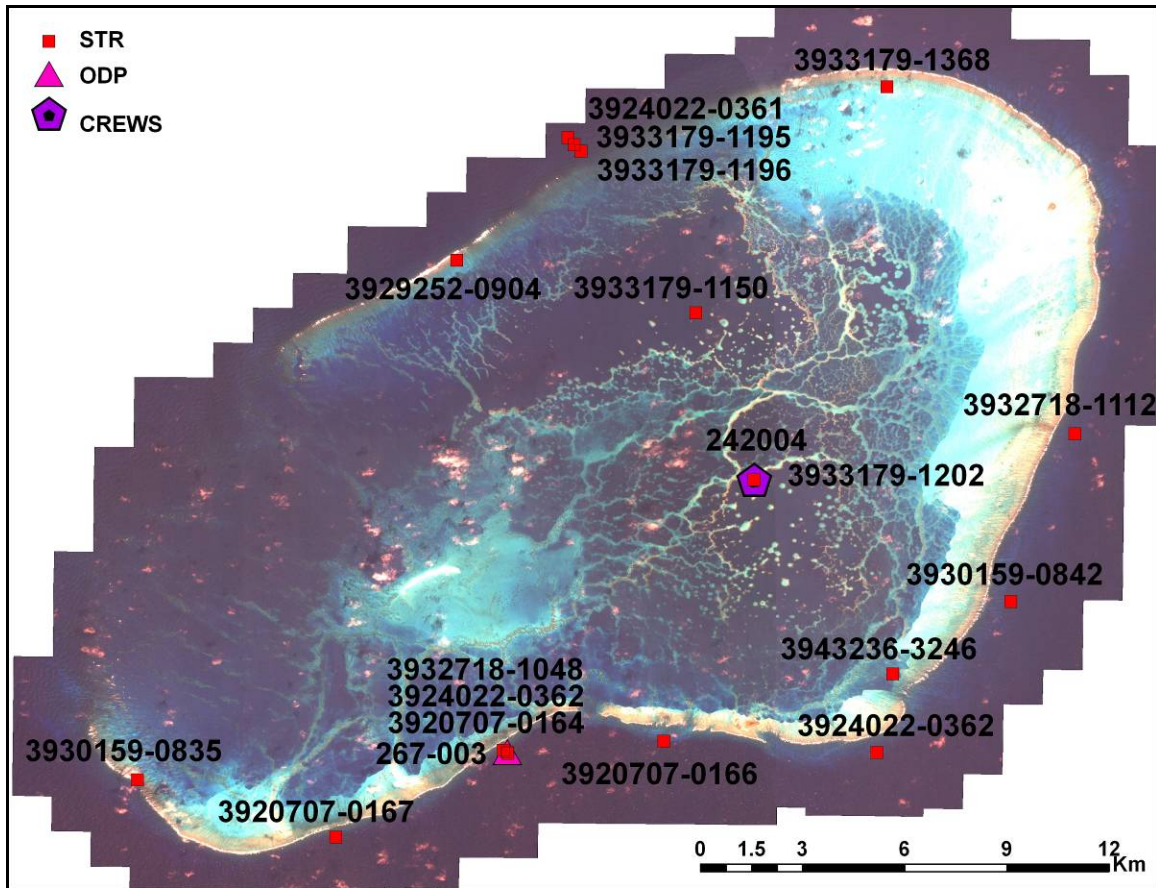
Figure D.4.2.3.--Geographic distribution of biomass around Laysan Island. Each species is represented by a legend color. Diameter of pie chart is proportional to total biomass of all species encountered on the underlying survey.

## Appendix E: Pearl and Hermes Atoll

### E.1. Oceanography and Water Quality

Moorings (Fig. E.1.1., Table E.1.1.)

Seventeen subsurface temperature recorders (STRs) were recovered and deployed at Pearl and Hermes during HI0809. Six of these are part of a south shore array deployed for the purpose of characterizing cold water intrusions (identified during the last Reef Assessment and Monitoring Program (RAMP) cruise to the region) along this portion of the atoll during the summer months. A Coral Reef Early Warning System (CREWS) buoy was removed and replaced by an sea surface temperature (SST) buoy with an STR on its anchor. A new ecological acoustic recorder (EAR) and STR were deployed together on the northwestern side of the reef. This EAR was deployed to monitor both biological acoustics as well as reported vessel traffic around the reef and in the lagoon.





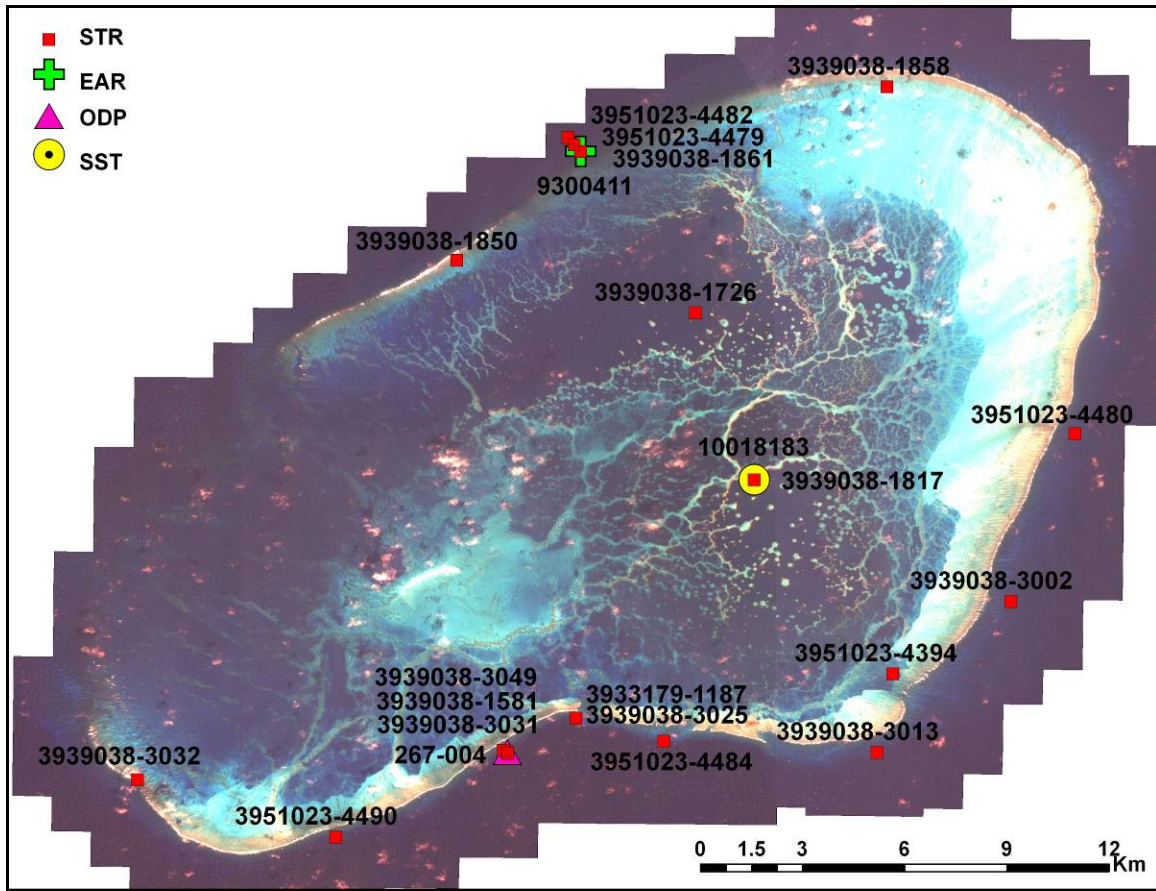


Figure E.1.1.--Moored Oceanographic instrumentation map for Pearl and Hermes Reef. Instruments recovered (top) and instruments deployed (bottom).

Table E.1.1.--Moored oceanographic instrumentation table for Pearl and Hermes Reef.

Instrument	Work	Serial Number	Latitude	Longitude	Data End	Depth
SST	Deployment	10018183	27.85393	-175.81592	22-SEP-08	7.62
CREWS	Retrieval	242004	27.85393	-175.81592	22-SEP-08	7.62
STR	Deployment	3939038-1817	27.85393	-175.81592	22-SEP-08	7.62
STR	Retrieval	3933179-1202	27.85393	-175.81592	22-SEP-08	7.62
ODP	Deployment	267-004	27.78206	-175.88112	23-SEP-08:	21.64
ODP	Retrieval	267-003	27.78206	-175.88112	23-SEP-08	21.64
STR	Deployment	3939038-3031	27.78168	-175.88093	23-SEP-08	38.10
STR	Retrieval	3920707-0164	27.78168	-175.88093	23-SEP-08	38.10
STR	Deployment	3939038-1581	27.78202	-175.88108	23-SEP-08	22.86
STR	Retrieval	3924022-0362	27.78202	-175.88108	23-SEP-08	22.86
STR	Deployment	3939038-3049	27.78251	-175.88220	23-SEP-08	13.11
STR	Retrieval	3932718-1048	27.78251	-175.88220	23-SEP-08	13.11
STR	Deployment	3939038-3025	27.79097	-175.86297	23-SEP-08	9.45
STR	Deployment	3933179-1187	27.79097	-175.86297	23-SEP-08	9.45
STR	Deployment	3951023-4482	27.94428	-175.86506	23-SEP-08	35.66
STR	Retrieval	3924022-0361	27.94428	-175.86506	23-SEP-08	35.66
EAR	Deployment	9300411	27.94057	-175.86171	23-SEP-08	16.46
STR	Deployment	3951023-4479	27.94057	-175.86171	23-SEP-08	16.46
STR	Retrieval	3933179-1196	27.94067	-175.86166	23-SEP-08	12.80
STR	Deployment	3939038-1861	27.94234	-175.86345	23-SEP-08	24.69
STR	Retrieval	3933179-1195	27.94234	-175.86345	23-SEP-08	24.69
STR	Deployment	3939038-1858	27.95763	-175.78082	23-SEP-08	1.22
STR	Retrieval	3933179-1368	27.95763	-175.78082	23-SEP-08	1.22
STR	Deployment	3939038-1726	27.89797	-175.83137	23-SEP-08	0.91



Instrument	Work	Serial Number	Latitude	Longitude	Data End	Depth
STR	Retrieval	3933179-1150	27.89795	-175.83135	23-SEP-08	0.91
STR	Deployment	3939038-1850	27.91187	-175.89442	24-SEP-08	2.74
STR	Retrieval	3929252-0904	27.91187	-175.89442	24-SEP-08	2.74
STR	Deployment	3951023-4480	27.86606	-175.73123	24-SEP-08	22.25
STR	Retrieval	3932718-1112	27.86606	-175.73123	24-SEP-08	22.25
STR	Deployment	3939038-3002	27.82180	-175.74816	24-SEP-08	21.64
STR	Retrieval	3930159-0842	27.82180	-175.74816	24-SEP-08	21.64
STR	Deployment	3951023-4394	27.80267	-175.77935	24-SEP-08	1.52
STR	Retrieval	3943236-3246	27.80267	-175.77935	24-SEP-08	1.52
STR	Deployment	3939038-3013	27.78194	-175.78349	24-SEP-08	23.16
STR	Retrieval	3924022-0362	27.78194	-175.78349	24-SEP-08	23.16
EAR	Other	EAR_13_9300239	NA	NA	NA	NA
STR	Deployment	3939038-3032	27.7747381	-175.978699	02-OCT-08	1.83
STR	Retrieval	3930159-0835	27.7747381	-175.97869	02-OCT-08	1.83
STR	Deployment	3951023-4490	27.7596724	-175.926322	02-OCT-08	22.25
STR	Retrieval	3920707-0167	27.7596724	-175.926322	02-OCT-08	22.25
STR	Deployment	3951023-4484	27.7848602	-175.839739	02-OCT-08	22.86
STR	Retrieval	3920707-0166	27.7848602	-175.839739	02-OCT-08	22.86

## Preliminary Mooring Results

Fifteen of the STRs recovered from Pearl and Hermes Reef yielded quality data sets that showed similar time series trends (Figs. E.1.2. and E.1.3.). Between September 2007 and September 2008, subsurface water temperatures around Pearl and Hermes fluctuated with seasonal variability typical for these latitudes; lows occurring between January and March ( $\sim 21$  °C) and highs between August and October ( $\sim 30$  °C). In addition to the typical seasonal variability observed, the STR array along the south shore showed atypical cold water pulses (particularly evident during the summer months of July through October) characterized by temperatures 5–8 °C cooler than the seasonal norm (Figs. 3 and 4.1). The coldest and most rapid temperature changes are occurring at the deeper sites ( $\sim 100$  feet) around early morning and late afternoon Midway Standard Time (Fig. E.1.4.). Results from a Fourier transformation on the temperature signal suggest that the frequency of these rapid temperature fluctuations is correlated with tidal oscillation at 12-hour (M2), and 24-hour (S2) intervals (Fig. E.1.5.).

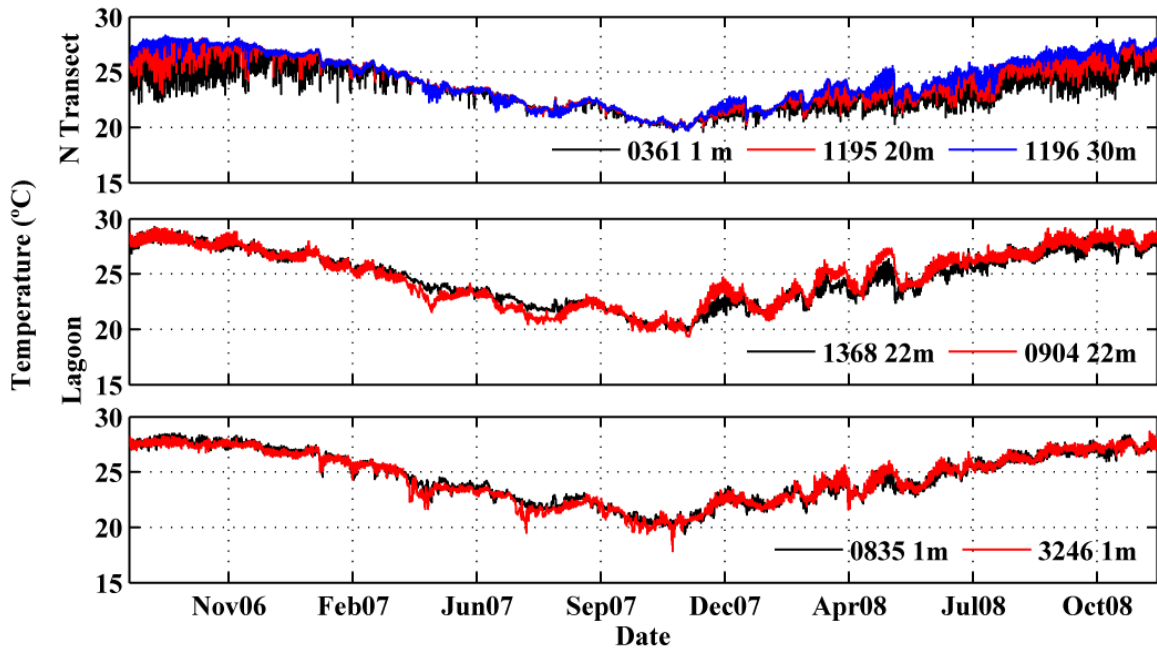


Figure E.1.2.--Temperature data obtained from 7 STR locations along the southern and eastern sides of the Atoll.

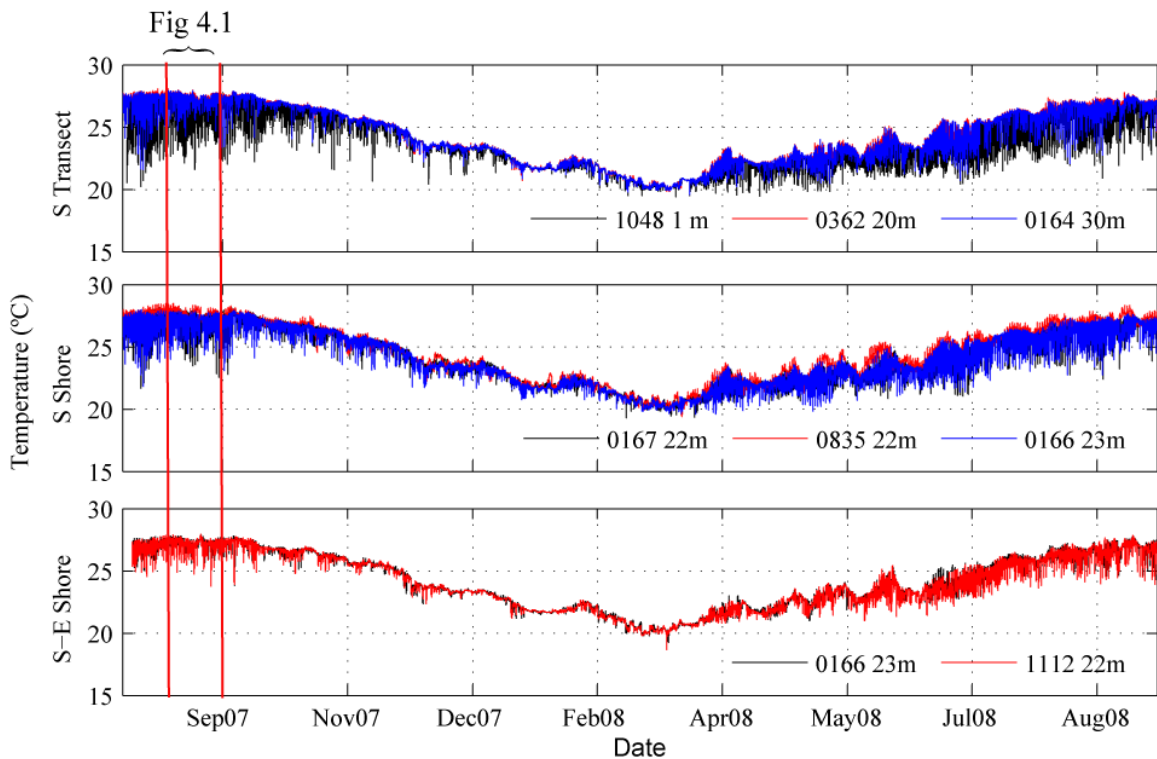


Figure E.1. 3.--Temperature data obtained from 8 STR locations along the southern and eastern sides of the Atoll. The red lines indicate the time period that is emphasized in Figure E.1. 4.

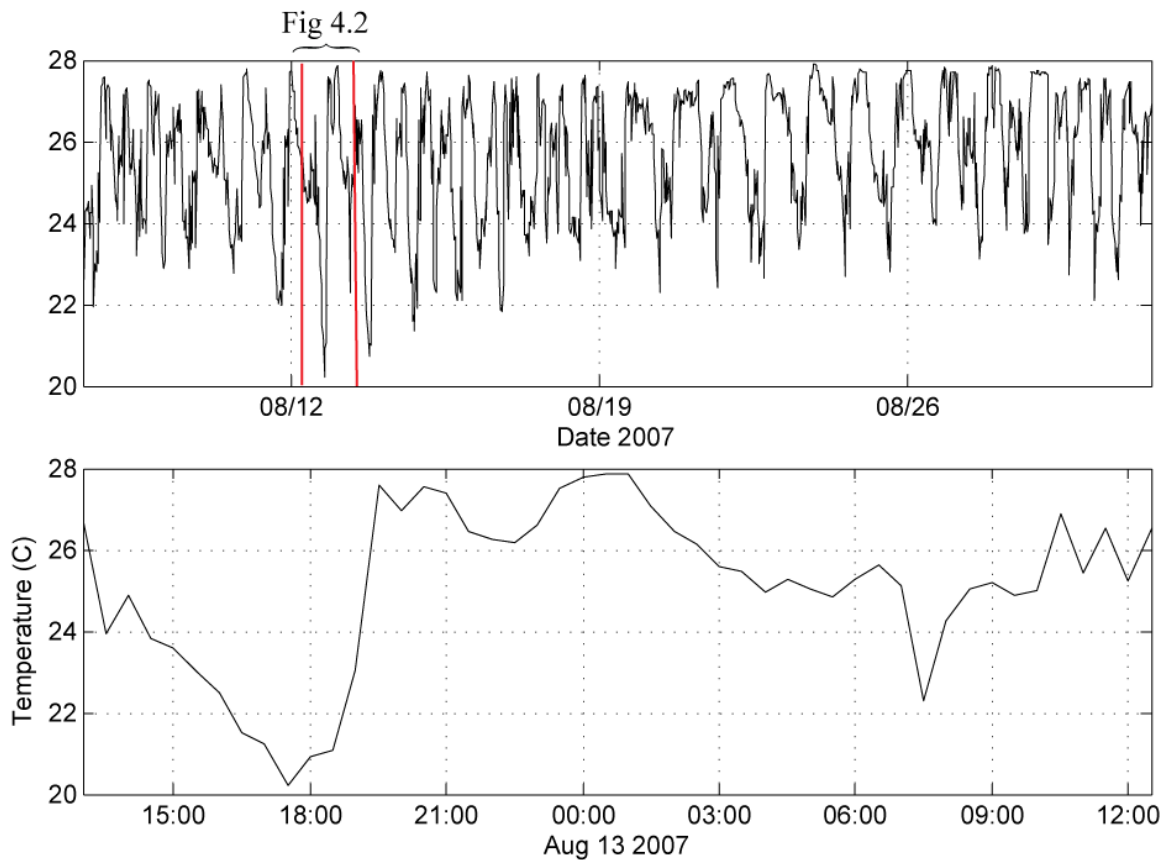


Figure E.1. 4.--(Top) Temperature time series obtained during the month of August 2007 from the deepest STR in the south shore transect (STR 0164). Red lines indicate the time period that is emphasized in Figure E.1. 3. (Bottom) Temperature time series for August 13, 2007 (Midway Standard Time).

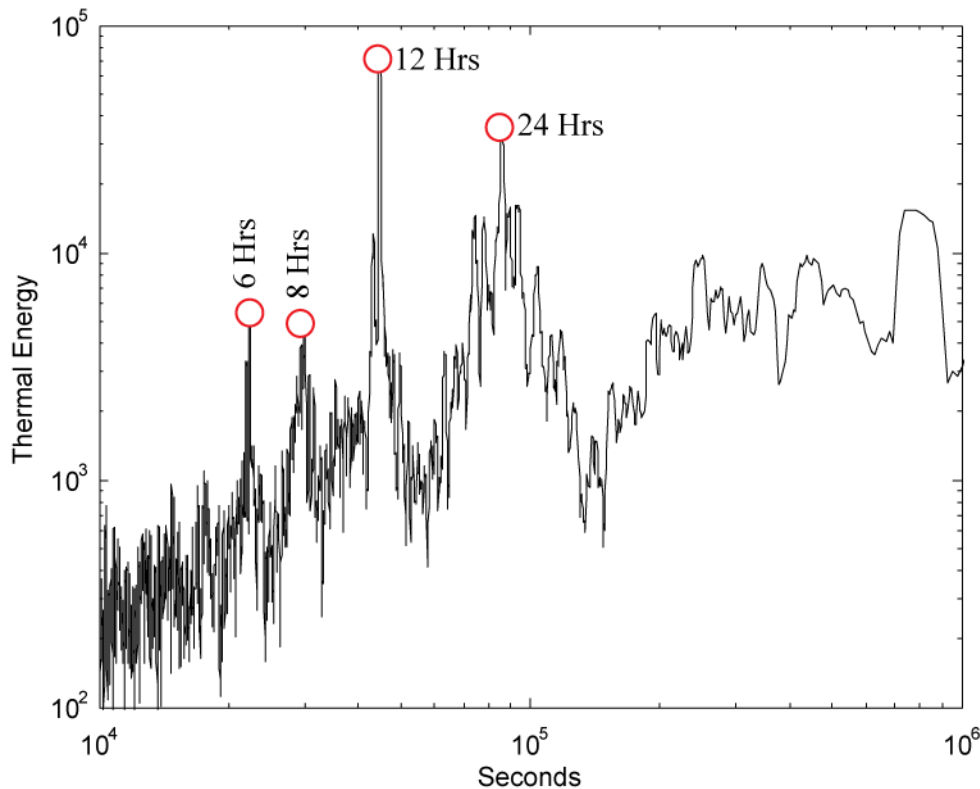


Figure E.1.5.--Frequency spectra of temperature peaks over the entire STR 0164 time series. Primary energy peaks occur at 12- and 24-hour time intervals with secondary peaks at 6 and 8 hours.

### Water Quality:

Twenty-four shallow-water conductivity, temperature and depth (CTD) casts were conducted at the 30-m bathymetric contour around Pearl and Hermes at approximately 2-nautical mile (nmi) intervals using a Seabird 19+ with additional dissolved oxygen (DO) and transmissometer sensors attached (Fig. E.1.6.). All shallow-water CTD casts were conducted between September 22 and 24, 2008. Additionally, thirteen CTD casts were conducted between October 2 and 3 at 1-hour intervals at a single point along the south shore (near the oceanographic data platform site) to try and capture the temporal variability of the cold water intrusions observed in this region.

Twenty discrete water samples were collected concurrently with shallow-water CTD casts at five of the shallow-water CTD sites using a daisy chain of Niskin bottles at 1 m, 10 m, 20 m and 30 m depth bins and will later be analyzed for nutrients and chlorophyll-*a*. Additionally, 14 discrete water samples (including one duplicate) were collected at the 30 m bin concurrently with each of the 13 CTD casts at the single point on the south shore site. All water samples were processed and stored according to protocol and will be sent out for analysis following the cruise.

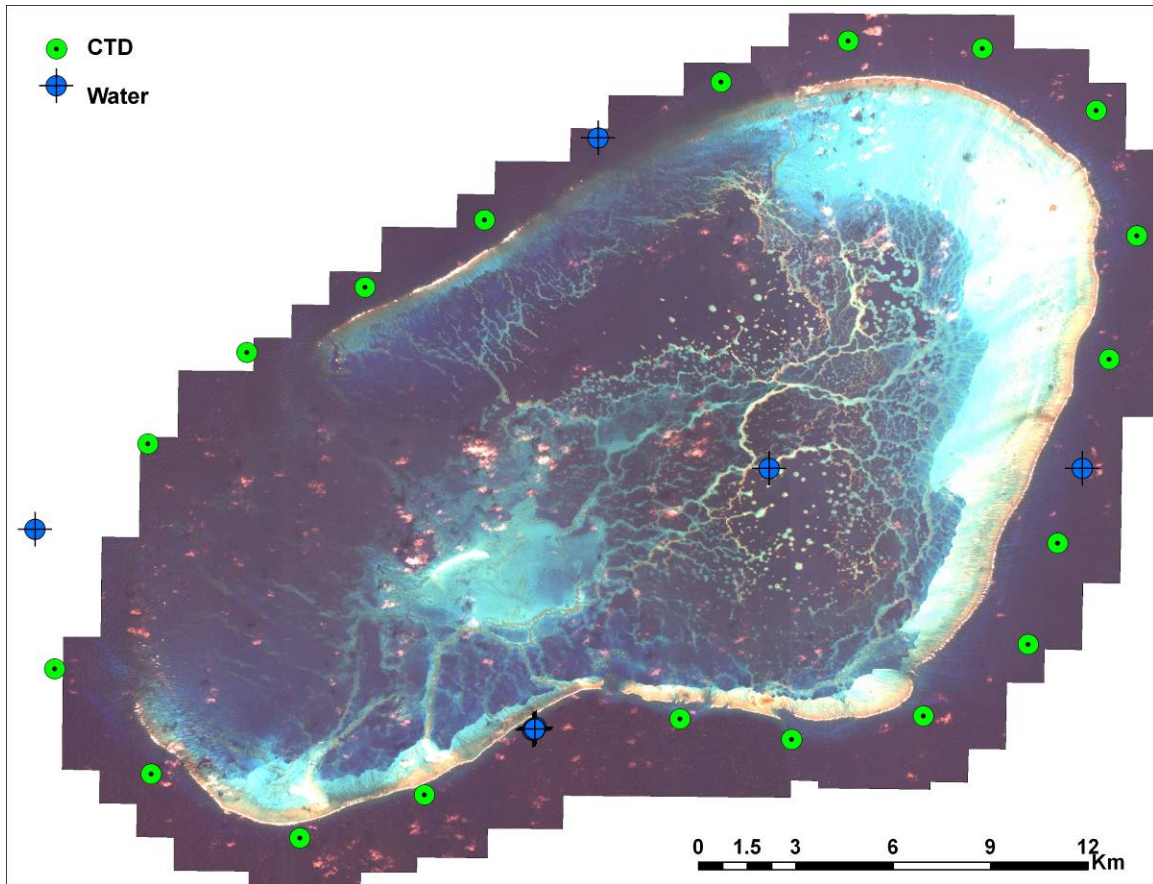


Figure E.1.6.--Shallow-water CTD and water sampling locations around Pearl and Hermes Atoll.

One permanent shipboard CTD site near Pearl and Hermes was sampled (Fig. E.1.7.). This cast included a CTD profile to 500 m depth, water samples that will be analyzed for chlorophyll and nutrients at the 3, 80, 100, 125 and 150 meters bins; and water samples that will be analyzed for carbonate chemistry (dissolved inorganic carbon and  $A_T$ ) at the 3 m and 125 m depth bins. The water samples were processed and stored according to protocol and will be sent out for analysis following the cruise.

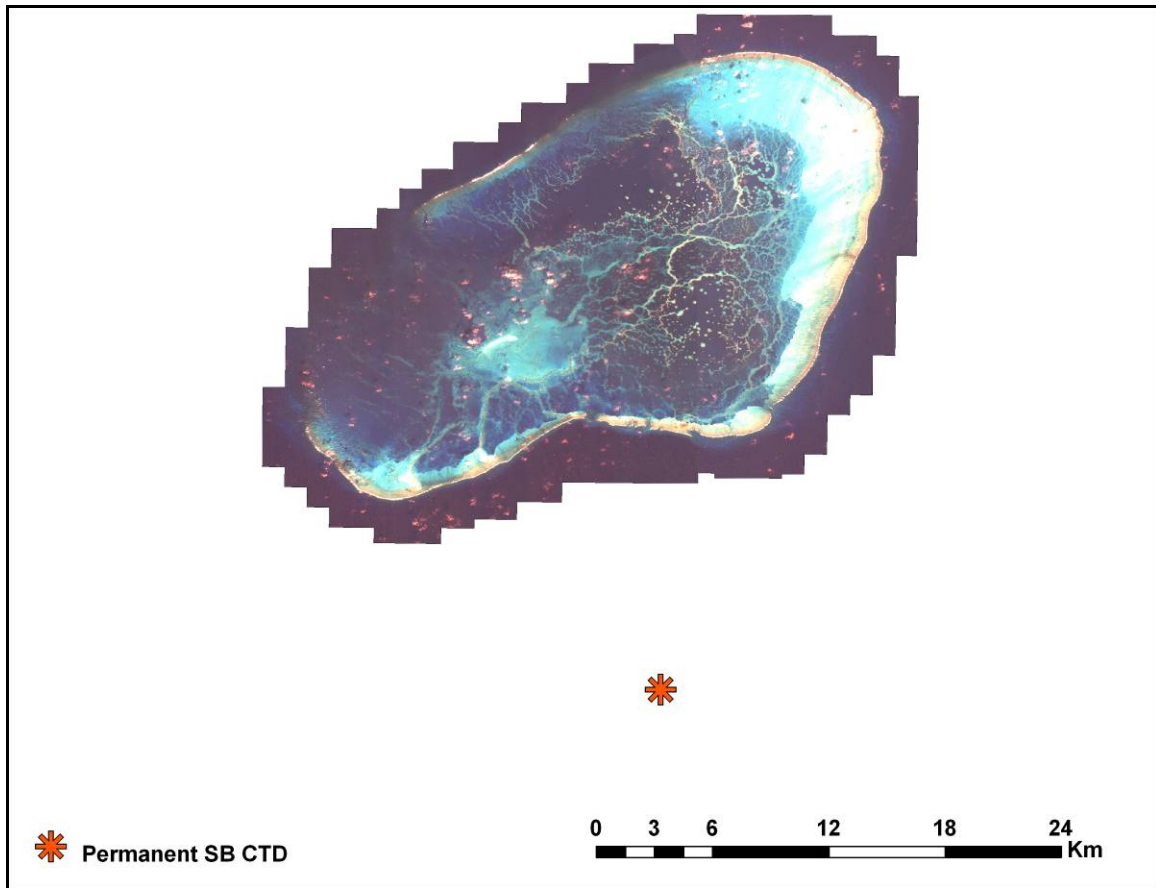


Figure E.1.7.--Permanent shipboard CTD location near Pearl and Hermes.

## E.2. Rapid Ecological Assessment (REA) Site Descriptions

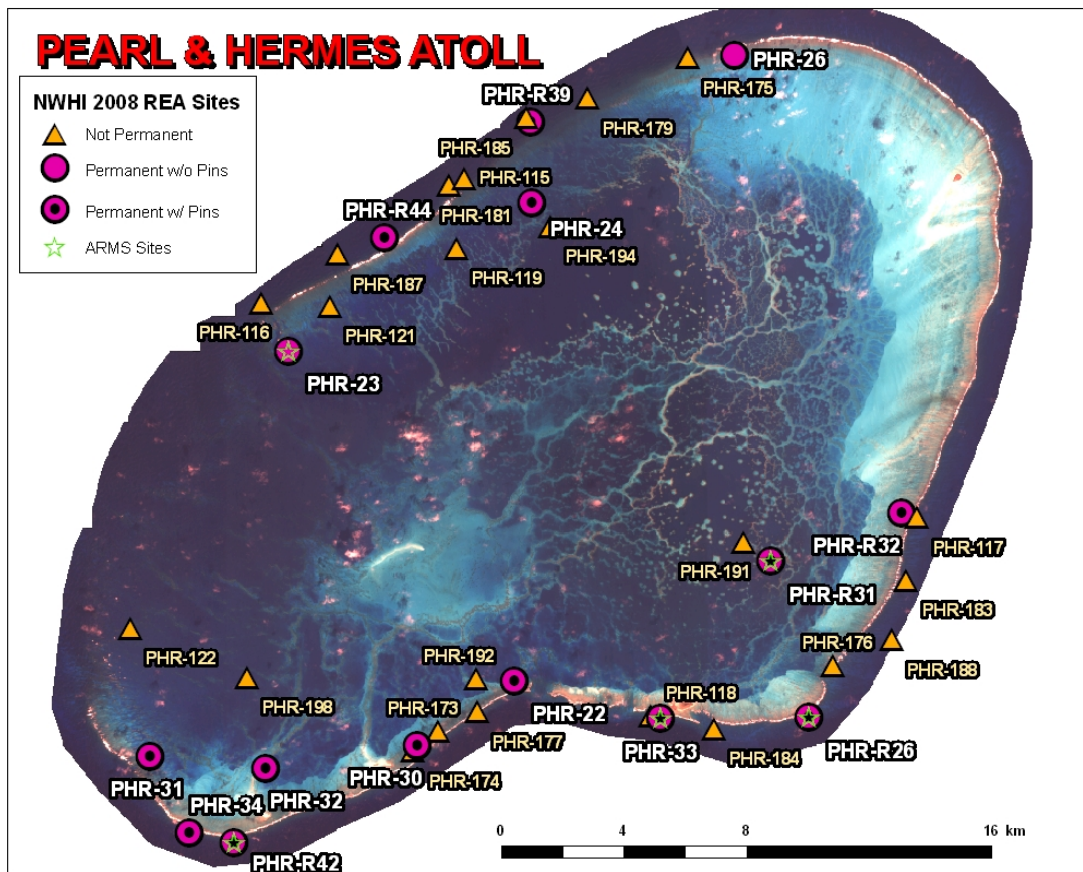


Figure E.2.1.--REA sites visited at Pearl and Hermes Atoll during HI0809.



Table E.2.1.--REA sites visited at Pearl and Hermes Atoll during HI-08-09 (see also Table A.2.2).

PHR-22	Backreef	1.0–1.5	27°47.715 N	175°51.997 W	2 Oct 2008
PHR-23	Backreef	5.2–6.4	27°52.868 N	175°55.967 W	3 Oct 2008
PHR-24	Backreef	4.5–6.4	27°55.180 N	175°51.688 W	23 Sept 2008
PHR-26	Backreef	1.5–2.1	27°57.479 N	175°48.131 W	3 Oct 2008
PHR-R26	Forereef	12.0–14.6	27°47.143 N	175°46.825 W	24 Sept 2008
PHR-30	Backreef	2.0–3.0	27°46.722 N	175°53.705 W	2 Oct 2008
PHR-31	Lagoon	6.4–9.1	27°46.532 N	175°58.401 W	22 Sept 2008
PHR-R31	Lagoon	10.7–16.0	27°49.586 N	175°47.484 W	24 Sept 2008
PHR-32	Lagoon	4.8–6.7	27°46.346 N	175°56.376 W	2 Oct 2008
PHR-R32	Backreef	0.9–1.2	27°50.072 N	175°45.210 W	24 Sept 2008
PHR-33	Forereef	10.6–12.7	27°47.128 N	175°49.425 W	2 Oct 2008
PHR-34	Forereef	10.7–18.6	27°45.353 N	175°57.707 W	22 Sept 2008
PHR-R39	Forereef	13.3–14.8	27°56.446 N	175°51.705 W	23 Sept 2008
PHR-R42	Forereef	11.3–15.5	27°45.188 N	175°56.926 W	22 Sept 2008
PHR-R44	Forereef	11.0–14.0	27°54.627 N	175°54.276 W	23 Sept 2008
PHR-121	Lagoon	4	27°53.548 N	175°55.237 W	3 Oct 2008
PHR-116	Forereef	13	27°53.665 N	175°56.347 W	3 Oct 2008
PHR-187	Forereef	13	27°54.357 N	175°55.103 W	3 Oct 2008
PHR-122	Lagoon	8	27°48.523 N	175°58.759 W	2 Oct 2008
PHR-198	Lagoon	15	27°47.252 N	175°56.699 W	2 Oct 2008
PHR-174	Backreef	2	27°46.607 N	175°53.777 W	2 Oct 2008
PHR-177	Forereef	4	27°47.214 N	175°52.655 W	2 Oct 2008
PHR-173	Backreef	2	27°46.920 N	175°53.344 W	2 Oct 2008
PHR-117	Forereef	12	27°50.257 N	175°44.914 W	24 Sept 2008
PHR-176	Forereef	5	27°47.936 N	175°46.398 W	24 Sept 2008
PHR-188	Forereef	19	27°48.345 N	175°45.373 W	24 Sept 2008
PHR-118	Forereef	10	27°46.955 N	175°48.495 W	24 Sept 2008
PHR-184	Forereef	10	27°46.955 N	175°48.495 W	24 Sept 2008
PHR-183	Forereef	13	27°49.271 N	175°15.106 W	24 Sept 2008
PHR-191	Lagoon	1	27°49.866 N	175°47.966 W	24 Sept 2008
PHR-185	Forereef	21	27°56.492 N	175°51.780 W	23 Sept 2008
PHR-119	Lagoon	14	27°54.446 N	175°53.025 W	23 Sept 2008
PHR-181	Forereef	14	27°55.437 N	175°53.142 W	23 Sept 2008
PHR-175	Forereef	4	27°57.425 N	175°48.952 W	23 Sept 2008
PHR-179	Forereef	9	27°56.793 N	175°50.713 W	23 Sept 2008
PHR-115	Forereef	10	27°55.536 N	175°52.890 W	23 Sept 2008
PHR-194	Lagoon	11	27°54.758 N	175°51.376 W	23 Sept 2008
PHR-192	Lagoon	2	27°47.738 N	175°52.668 W	22 Sept 2008



PHR-23

03 October 2008

Located on the slope of a patch reef within the lagoon, the transects were laid along the side of the patch. The benthos at this site was dominated by highly epiphytized *Halimeda opuntia*, crustose coralline red algae and turf algae. Additionally, *Lobophora variegata*, a species of *Peyssonnelia*, *Dictyosphaeria cavernosa*, *Dictyota ceylanica*, *Turbinaria ornata*, *Codium edule*, and *C. arabicum* were documented during the line point intercept (LPI) survey, and *Dictyosphaeria versluysii* was documented during the Roving Diver survey. The overall coral cover was low (2%) at this patch reef site. Coral cover was mostly *Porites compressa*, *Monitpora capitata*, and *Porites lobata*. Bivalves were a major component of the slope substrate, as were the species *Arca ventricosa* and *Spondylus violacescens*. There were numerous large holes and overhangs but very little abundance of macroinvertebrates. However, encrusting organisms such as sponges and tunicates were prevalent. There was a low abundance of the invertebrate *Echinometra mathaei*. Fish diversity and abundance were fairly high at this site. Numerous small caves in the reef housed a variety of nocturnal species such as *Sargocentron xantherythrum*, *Neoniphon sammara*, and *Myripristis amaena*. The common diurnal species such as *Chlorurus perspicillatus*, *Thalassoma duperrey*, and *Stegastes fasciolatus* were also in abundance. Numerous *Chaetodon miliaris* were counted on transect as well and were seen feeding in the water column, visible from the surface. One *Triaenodon obesus* and several *Aprion virescens* were also seen in the vicinity, along with a few *Caranx melampygus* that made a quick appearance.

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PHR-26

03 October 2008

Coral cover was moderately high (34.8%) composed mostly of large *Monitpora capitata* mounds which had considerable partial mortality with the majority of live coral being found on lower portions and sides of the mounds. *Montipora flabbellata* was often encrusting the tops of the mounds. Many *M. capitata* colonies appeared pale compared to colonies which had some shading. Colonies of *M. patula*, were less abundant, but colonies that were seen appeared to be bleached. Three cases of skeletal growth anomalies on *Monitpora capitata* were observed just off transect. The algal community was dominated by turf algae and crustose coralline red algae with a relatively low percent cover of *Microdictyon setchellianum* and *Laurencia galtsoffii*. Additionally, *Halimeda discoidea* and *H. velasquezii* were documented during the LPI survey and a species of *Neomeris*, a cyanophyte, *Halimeda opuntia*, and *Caulerpa serrulata* were documented during the Roving Diver survey. Very few macroinvertebrate species were present at the site and there was a low abundance of the urchin species *Echinometra mathaei*. Fish diversity and abundance were relatively low at this site. *Chlorurus perspicillatus* was fairly abundant, with several large adults counted on transect as well as off. The most abundant species below 20 cm include *Thalassoma duperrey*, *Stegastes fasciolatus*, and *Stethojulis balteata*. A school of approximately 30 *Mulloidichthys vanicolensis* in the 20-cm range was seen off transect, along with one *Triaenodon obesus* and one *Carcharhinus galapagensis*.

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PHR-32

02 October 2008

S-SW, shallow internal lagoon reef slope. Depth range: 4.8–6.7 m, visibility ~ 15 m. Slope (~ 15°) of SW lagoon patch reef with moderately low topographic relief. This site is mainly composed of bioeroded pavement bioeroded with benthos dominated by highly epiphytized *Microdictyon setchellianum* with a low percent cover of *Stypopodium flabelliforme*. Additionally, *Dictyosphaeria cavernosa* and a species of *Padina* were documented during the LPI survey and *Caulerpa serrulata*, *Halimeda discoidea*, *Laurencia galtsoffii*, and a species of *Liagora* were documented on the Roving Diver survey. Coral cover was 3.6% composed of a sparse assemblage of *Pocillopora meandrina* and *P. damicornis* and with the exception of trapezoid crabs, macro-invertebrates were low at this site. *Echinometra* urchins, *Coralliophila* snails, and *Calcinus* hermit crabs were occasional. This site was also relatively low in fish abundance and diversity. The most common fishes encountered were the parrotfish *Calotomus zonarchus* and the wrasse *Thalassoma duperrey*. Off transect recordings included 13 large *Naso unicornis* as well as an eagle ray.

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PHR-30

02 October 2008

S-SW, shallow backreef. Depth range: 2–3 m, visibility ~ 20 m, temperature: 26 °C. Heavily bioeroded carbonate with sparse rubble and sand pockets. This area was highly scoured by wave action, and the benthos was dominated by turf algae, *Laurencia galtsoffii*, and *Microdictyon setchellianum*. A species of *Liagora*, *Lobophora variegata*, and crustose coralline red algae were also documented on the LPI survey. The only other species documented during the Roving Diver survey were *Dictyosphaeria versluysii* and *Stypopodium flabelliforme*. There was low coral cover (6%) composed by a sparse assemblage of *Pocillopora* and *Porites lobata* colonies. At site PHR-22, the fishes at this site were sparse. *Thalassoma duperrey* made the strongest showing, but was still not numerous.

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PHR-22

02 October 2008

S; shallow backreef. Depth range: 1–1.5 m, Visibility ~ 20 m. South patch reef with low topographic and sparse rubble, sand pockets, and solution holes. The coral cover was low (3.2%) and composed mostly of scattered *Pocillopora meandrina* and *Leptastrea pupurea* colonies of which considerable partial mortality was seen in the latter. The benthos was dominated by highly epiphytized and grazed *Microdictyon setchellianum* and turf algae. A species of *Liagora*, *Dictyosphaeria versluysii* and non-geniculate branched coralline red algae were also documented during the LPI survey. *Stypopodium flabelliforme* was documented during the Roving Diver survey. Fishes were almost completely absent at this site. A few small wrasses, hawkfish, a single filefish and a single scorpionfish were counted on the first two transects; the third transect was

completely devoid of fishes. Large unicornfish were seen in the area but never wandered into the transect.

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#### PHR-33

02 October 2008

S; ocean fringing forereef; depth range 10.6–12.7 m; visibility 25 m. Live coral cover was extremely low (1.6%) composed of a sparse assemblage of *Porites lobata*, *Pocillopora*, and *Pssamocora stellata*. Pavement was relatively uniform on transect; however numerous holes in the reef surrounded the site. Interestingly, in the middle of the dive an influx of colder water (estimated at 4–5 °C cooler than previous water temp.) flushed past the site which the oceanography team has documented as cold water upwelling. This site was almost a monotypic culture of highly turf-colonized *Microdictyon setchellianum* with small individuals of *Halimeda velasquezii*, *H. discoidea*, and *Lobophora variegata*. Additionally, a species of *Neomeris*, *Turbinaria ornata*, a species of *Jania*, and *Styopodium flabelliforme* were documented during the LPI survey.

Both the boring urchins, *Echinostrephus aciculatus* and *Echinometra mathaei*, were abundant. Two of the *Holothuria* sp., commonly named Chocolate Chip sea cucumber, were seen. This site had low abundance and diversity of fishes. Most sightings were of singular fish, with only a few species seen more than once, such as *Thalassoma duperrey*. A few large fishes were sighted off transect and included 9 *Caranx ignobilis* and 8 *Caranx melampygus*. No other large fishes were sighted.

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#### PHR-R42

22 September 2008

S-SW, fringing forereef; depth range: 11.3–15.5 m, visibility ~30 m. Carbonate pavement and rubble heavily bioeroded with moderate topographic complexity. The southern facing forereef site was dominated by almost a monotypic meadow of highly epiphytized *Microdictyon setchellianum* with the LPI survey also documenting a few individuals of *Halimeda discoidea*, *Lobophora variegata*, *Padina* sp., *Liagora* sp. and turf algae colonizing either rubble or sand. *Halimeda velasquezii*, a species of *Neomeris*, *Dictyosphaeria versluysii* and non-geniculated crustose coralline red algae were documented during the Roving Diver survey. Coral cover was low (5.8%) mainly composed of *Porites lobata*, *Leptastrea purpurea*, *Psammocora stellata* and *Pocillopora* sp. Ten scleractinian species were observed within the survey area. Small colonies (< 5 cm) of *Psammocora stellata* were abundant while colonies of *Leptastrea* were mostly dead with any living tissue appearing pale. Interestingly, about 5 meters past the end of transect two; a massive field of *Pocillopora* sp. was encountered. Several crown-of-thorns (COTs) were seen in the area where COTs predation was estimated to be impacting a small percentage of the *Pocillopora* colonies. There was moderate diversity in fish species at site R-42. Plankivores dominated the community, with species such as *Chromis ovalis*, *Chaetodon miliaris*, *C. vanderbilti*, *Dascyllus albisella*, and *C. hanui* being the most abundant fishes in the immediate area. Other noteworthy species fairly abundant at this site include *Genicanthus personatus*, *C. kleinii*, and *Apolemichthys*

*arcuatus*. Several large *Caranx ignobilis* and *Aprion virescens* were also present in the area off transect.

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PHR-34

22 September 2008

W-SW; ocean fringing forereef; depth range 10.7–18.6 m; visibility 35 m. Substantial topographic complexity with large spur-and-groove channels dominated by *Porites* and *Pocilloporids*. The boring urchins, *Echinostephus aciculatus* and *Echinometra matheai* were abundant. *Holothuria atra* was common. Coral cover was moderate (18.4%) mainly composed of *Porites lobata*, *Pocillopra*, and *Montipora* species. Coral diversity was relatively high with 15 scleractinian species observed within the survey area. A large number of *Pocillopora* recruits were observed, many measuring less than 2 cm. Corals seemed relatively healthy with few signs of bleaching and compromised health conditions. This site had a low overall abundance of macroalgae. The algal community was dominated by turf-colonized pavement with some *Lobophora variegata*, crustose coralline red algae and small individuals of *Halimeda velasquezii* that were only moderately colonized with turf algae. *Microdictyon setchellianum*, *Halimeda discoidea*, *Dictyota ceylanica* and a species of *Valonia* were documented during the Roving Diver survey. Fish diversity and abundance were moderate and increased from replicates A to C. The most common species found on-transect included *Thalassoma duperrey*, *Chromis hanui*, *C. vanderbilti* and *Paracirrhites arcatus*. Many large trevally were seen off transect, including a school of 40+ *Caranx melampygus*. A group of approximately 20 *Aprion virescens* were seen at the beginning of the survey, as well as large schools of *C. ovalis*. Upon descending to the site, an adult grey reef shark and whitetip reef shark were seen, as well as a juvenile/subadult Galapagos shark.

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PHR-31

22 September 2008

Site followed along the edge of a patch reef near Seal Kittery Island. This site was dominated by stands of *Montipora capitata* on the upward facing sides of a wall and highly epiphytized, almost monotypic *Microdictyon setchellianum* on the overhangs. *Halimeda distorta* was documented in patches among the *M. setchellianum* and was also highly epiphytized. *Dictyosphaeria versluysii* and crustose coralline red algae were documented during the Roving Diver survey. A species of *Neomeris* was noted to be more abundant than at other sites visited, despite it not being commonly found on the LPI transect line. Live coral cover was 36.4%, mainly composed of *Montipora capitata* and a few scattered colonies of *Montipora flabellata*. Several colonies of *Montipora turgescens* were noted off transect. Most of the *Montipora* colonies exhibited signs of bleaching with many colonies being affected by algae growth. In addition, colonies of *Montipora flabellata*, *M. Capitata*, and *M. patula* observed adjacent to the survey area showed signs of subacute tissue loss from an unknown disease. Coral samples were collected for further analysis. Vermitid snails were abundant. The holothuroids, *Holothuria atra*, *H. whitemai*, and *Actinopyga obesa* were common. Off transect in the sand were many tiny sea cucumbers, possibly juvenile *H. atra*. Fish diversity and counts

were relatively low here, with *Chromis ovalis* and *Dascyllus albisella* being the most abundant species in the area.

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PHR-R44

23 September 2008

W-NW; ocean fringing forereef; depth range: 13.3–14.8 m; visibility: 15 m. This medium relief spur-and-groove site was composed of carbonate and sand and was dominated by turf-colonized pavement, crustose coralline red algae and small individuals of *Halimeda velasquezii* which were moderately epiphytized. *Lobophora variegata* was also documented during the LPI survey. A species of *Neomeris*, non-geniculated coralline red algae, cyanophytes, *Dictyota ceylanica*, *Caulerpa serrulata*, and *Spyridea filamentosa* were also documented during the Roving Diver survey. There was a moderately high coral cover (21.2%) primarily composed of moderately fissioned *Porites lobata* colonies. Site was moderately rich in coral species with 10 anthozoan species enumerated within the survey area. Approximately 45 *Caranx ignobilis*, ranging from 85 and 120 cm, were constantly surrounding the divers on each of the transects. At least three different *Triaenodon obesus* were identified and seen swimming off transect at various times. A few *Aprion virescens* were also seen off transect. Very few other fish were seen due to the constant presence of the *C. ignobilis*, but 9 other species were identified and recorded, the most prevalent being *Chromis ovalis*.

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PHR-R39

23 September 2008

N; ocean fringing forereef; depth range: 11.0–14 m; visibility: 15 m. Spur-and-groove environment with extremely high complexity. This site was dominated by turf-colonized dead coral, crustose coralline red algae and *Lobophora variegata* with low to moderate percent cover of *Halimeda velasquezii*. *Portieria hornemanii*, *Microdictyon setchellianum*, and a species of *Neomeris* were also documented during the LPI survey. Cyanophytes, *Dictyota ceylanica*, *Codium arabicum*, *Dictyosphaeria versluisii*, *D. cavernosa*, *Caulerpa peltata*, a species of *Laurencia*, *Gibsmithia hawaiiensis*, a species of *Peysonnelia*, and *Halimeda discoidea* were documented during the Roving Diver survey in holes in the substrate. Coral cover was low 1.6%, but a relatively high number of species were observed within the survey area (11 anthozoan species) including numerous patches of *Fungia scutaria* and *Pavona maldivensis* colonies. Fish diversity at this site was relatively low. More *Ctenochaetus strigosus* were seen at this site compared to others surveyed at Pearl and Hermes. On average, individuals were also larger in this area than at other sites. There was also an abundance of *Acanthurus leucoparius* and *A. triostegus*. Approximately 10 *Caranx ignobilis* and 1 *C. melampygus* were seen off transect. Other species in less abundance but still quite numerous included *Stegastes fasciolatus* and *Chlorurus sordidus*.

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PHR-24

23 September 2008

North; shallow, internal lagoon patch reef slope. Depth range: 4.5–6.4 m, visibility ~4 m. Carbonate framework heavily colonized by *Halimeda* and virtually devoid of non-cryptic macroinvertebrates, with the exception of numerous *Acra ventricosa* lining the patch reef walls. Off transect on the flats were several holothuroids, including *Holothuria whitmari*, *H. atra*, and *Actinopyga obesa*. One *Acanthaster planci* was seen eating a Montiporid. This site was almost a monotypic stand of individuals of the genus *Halimeda*. *Halimeda distorta* is the dominant species, with *H. discoidea*, *H. velasquezii*, and *Dictyosphaeria versluysii* also being documented during the LPI survey. All individuals of *Halimeda* were highly epiphytized with a cyanobacteria. This same cyanobacteria covered almost all other surfaces aside from live coral. No additional species of algae were found during the Roving Diver survey. There was low coral cover (8%) dominated by sparse *Porites compressa* colonies. Six anthozoan species were observed within the survey area with colonies of *Tubastraea coccinea* seen on the underside of caves. Fish diversity and abundance at this site was relatively low. Species with individuals in abundance include *Chlorurus sordidus*, *Stegastes fasciolatus*, and *Thalassoma duperrey*. There were numerous *Chromis ovalis*, one large *Caranx ignobilis*, and several *Kyphosidae* off transect as well.

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PHR-R32

24 September 2008

East, shallow backreef. Depth range: 0.9–1.2 m. Visibility ~ 12 m. Coralline pavement, algal- and sand-coated carbonate and rubble with limited topographic complexity. This very shallow back reef region experienced strong surge and current from the adjacent forereef area. The area was dominated by turf algae and *Microdictyon setchellianum*. Additionally, non-geniculate coralline red algae and a species of *Liagora* were found on the LPI survey transect line and *Turbinaria ornate*, and a species of *Laurencia* were documented during the Roving Diver survey. The boring urchin, *Echinometra mathaei*, was the dominant macroinvertebrate followed by the sea cucumber, *Holothuria atra*. The brittlestar, *Ophiocoma pica* was widespread in the dead coral heads and the urchin, *Echinostrephus aciculatus* was rare. Fish abundance and diversity was very low, with the most common species being *Coris venusta*. A school of unidentified silver fish in the surface waters was seen on transect but there were no large fish sightings off transect.

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PHR-R31

24 September 2008

E-SE. Inside lagoon reticulate reef; forereef slope. Depth range: 10.7–16 m. Visibility < 10 m. relief. Slope (~ 45°) of SE lagoon patch reef composed almost exclusively of dense thickets of *Porites compressa*. The dead branches of *P. compressa* were colonized by turf algae, which was the dominant algal functional group. No other algae was documented during the LPI survey. Additionally, a cyanophyte, a species of *Laurencia*, *Caulerpa racemosa*, *Halimeda distorta*, and *Microdictyon setchellianum* were documented during the Roving Diver survey. Non-cryptic macroinvertebrates were rare,

and no echinoids were seen. The sea star, *Linckia multifora*, was common. In the shallows off transect, several of the sea slug, *Plakobranthus ocellatus*, and the anemone, *Aiptasia pulchella*, were seen. Vermitids snails were found to be widespread, bored into the *P. compressa*. This site contained a low abundance and diversity of fish. The most common fishes found were juvenile parrotfish of the genus *Chlorurus sordidus*, *Scarus dubius* and *S. psitticus*. Off transect recordings included an adult whitetip shark as well as the butterflyfishes, *Chaetodon lunulatus* and *C. aurigus*.

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#### PHR-R26

24 September 2008

This low relief spur-and-groove site was dominated by *Microdictyon setchellianum* with small individuals of *Halimeda velasquezii*, a species of *Laurencia*, non-geniculated coralline algae, and a species of *Padina* interspersed among the *Microdictyon* meadow. The *M. setchellianum* did not appear to be heavily grazed. *Halimeda discoidea*, a species of *Neomeris*, and *Dictyota ceylanica* were documented during the Roving Diver survey. The sea urchins, *Echinostrephus aciculatus* and *Echinometra mathaei* were prevalent and four species of sea cucumbers were noted: *Holothuria atra*, *H. Whitmaei*, *Actinopyga obesa*, and *Bohadschia paradoxa*. Smaller fishes were abundant at this site, including the damsels *Chromis hanui* and *C. verater*, the saddleback wrasse *Thalassoma duperrey*. On the third transect *Pseudanthias thompsoni* were recorded, the only sighting of this anthias to date during this cruise. The jobfish, *Aprion virescens*, was a larger species seen on transect, while half a dozen *Caranx melampygus* were seen off transect. Also of note off transect was a large school (~ 60) of the Hawaiian (and Johnston Island) endemic butterflyfish, *Chaetodon miliaris*.

#### Randomly selected Fish Sites:

PHR-115      9/23/08

N 27°55.536    W 175°52.890

Depth: 10 m

This site is located in the northwestern forereef of Pearl and Hermes Atoll. It was established by the REA fish team as a new sampling location in the moderate forereef stratum. While rugosity was high at this site, coral cover was low. There was less than 5% live coral cover, comprised mainly of *Porites lobata* and *Montipora* spp. The majority of the substrate consisted of bare rock with coralline algae and large patches of *halimeda*. Fish abundance and diversity were relatively low at this site as well, with the most common species being *Stegastes fasciolatus* and *Thalassoma duperrey*. Five *Caranx ignobilis* were noted outside of the transect boundaries, as well as a whitetip reef shark and a few large crown-of-thorns starfish.

PHR-117      9/24/08  
N 27° 50.257 W 175° 44.914  
Depth: 12 m

This site was located on the eastern forereef of Pearl and Hermes. It was established by the REA fish team as a new sampling location in the moderate forereef stratum. It was in spur-and-groove habitat, with moderate relief and complexity. There were small basalt mounds with grooves and caves with sand patches. Coral cover was very low at less than 3% in this algae-dominated site. *Dictospheria* spp. was the dominant algae with approximately 90% cover in areas of hard substrate. There was a whitetip reef shark, *Triaenodon obesus* at 160 cm, and *Caraharhinus galapagensis* at 250 cm off transect. Ten *Caranx ignobilis*, 3 morwongs, *Goniistius vittatus* and 3 *Genicanthus personatus*, 2 males and 1 female were sited off transect. This site has good species diversity.

PHR-118    9/24/08  
N 27°46.955    W 175°48.495  
Depth: 10 m

This site is located in the southern forereef of Pearl and Hermes Atoll. It was established by the REA fish team as a new sampling location in the moderate forereef stratum. The substrate here was mostly rubble and sand with very low coral cover (~ 2%); complexity was low as well. Large fishes counted included *Naso unicornis*, *Aprion virescens* and *Caranx ignobilis*, which was not only seen on the transect, but tried to eat it. This large ulua was part of a roaming gang that patrolled the area during the entire dive. On a more benign note, about 2 dozen rainbow runners (*Elegatis bipinnulatis*) made a brief appearance off transect. Also of note off transect was a cute little masked angel.

PHR-119      9/23/08  
N 27° 54.446 W 175° 53.025  
Depth: 14 m

This site is located in the northern lagoon of Pearl and Hermes Atoll. It was established by the REA fish team as a new sampling location in the moderate lagoon stratum. *Porites compressa* was the dominant coral at this patch reef, with 80% coral cover. The habitat had high relief and complexity due to the compressa fields and mounds. Juvenile scarids were the dominant fish at this site, which was otherwise low in species diversity.

PHR-175      9/23/08  
N 27°57.425    W 175°48.952  
Depth: 4 m

This site is located in the northern forereef of Pearl and Hermes Atoll. It was established by the REA fish team as a new sampling location in the shallow forereef stratum. Complexity was high while coral cover was very low (~ 2%), with the occasional head of *Pocillopora meandrina* and sparse patches of *Porites lobata*. Few large fishes were seen on transect, with the exception of three omilu (*Caranx melampygus*) and the occasional spectacled parrotfish (*Chlorurus perspicillatus*). The usual array of *Thalassoma duperrey* and *Ctenochaetus strigosus* were seen, while off transect a single *Caranx ignobilis* investigated the divers.



PHR-176 9/24/08  
N 27° 47.936 W 175° 46.398  
Depth: 5 m

This site was located on the southeastern forereef of Pearl and Hermes. It was established by the REA fish team as a new sampling location in the moderate forereef stratum. It consisted of spur and grooves located close to a channel pass in the reef to the lagoon, and was adjacent to a high surf (high water energy) area. Habitat complexity was moderate, with caves, cracks and sand patches. Coral cover was low at less than 3%, with a few scattered *Pocillopora* spp. colonies. Algae dominated the hard substrate where *Dictospheria* spp., *Turbinaria*, and turf were present. There were several small (100–120 cm) *Caraharhinus galapagensis*, and several large wrasses, *Thalassoma purpureum*, *T. ballieui*, and *Coris flavovittata*.

PHR-179 9/23/08  
N 27°56.793 W 175°50.713  
Depth: 9 m

This site is located in the northwestern forereef of Pearl and Hermes Atoll. It was established by the REA fish team as a new sampling location in the moderate forereef stratum. The site was composed of highly rugose substrate, forming deep caverns and crevices more than 5 m deep. Coral cover was extremely low and the only growth found on the substrate consisted of coralline algae and *halimeda*. Diversity was somewhat low with the most abundant species consisting of the damselfish *Stegastes fasciolatus* and the wrasse *Thalassoma duperrey*. Large *Chlorurus perspicillatus* were also relatively abundant. Off transect sightings included a couple of large *Aprion virescens* and *Caranx melampygus* as well as large adult *Bodianus bilunulatus* and *Sargocentron spiniferum*.

PHR-181 9/23/08  
N 27°55.437 W 175°53.142  
Depth: 14 m

This site is located in the northwestern forereef of Pearl and Hermes Atoll. It was established by the REA fish team as a new sampling location in the moderate forereef stratum. *Porites lobata* covered approximately 40% of this medium to low rugosity reef, with the rest of the substrate comprising coralline algae, *halimeda* and other green algae. Off transect sightings included 2 inquisitive whitetip reef sharks as well as a few *Aprion virescens*, *Caranx melampygus* and *C. ignobilis*. Abundance and diversity of fishes within the transect boundaries were low, and the only species of any abundance was *Thalassoma duperrey*.

PHR-183 9/24/2008  
N 27° 49.271 W 175° 15.106  
Depth: 13 m

Site 183 is located on the southeast forereef of Pearl and Hermes. It was established by the REA fish team as a new sampling location in the moderate forereef stratum. The substrate is composed of low complexity and minimal relief. Sand and rubble channels weave around patches of reef heavily covered (80 percent) in *Dictospheria*. There was also a moderate current flowing in the southwesterly direction. Visibility was good at

approximately 80 feet. Ten *Caranx ignobilis* in the 90 cm range were in the area, along with a school of 30 *Elagatis bipinnulatus* higher in the water column. Fish diversity and abundance were relatively low, with *Thalassoma duperrey*, *Chromis vanderbilti*, and *C. hanui* being the most abundant species.

PHR-184      9/24/2008  
N 27°46.95   W 175°48.495  
Depth: 10 m

This site is located in the southern forereef of Pearl and Hermes Atoll. It was established by the REA fish team as a new sampling location in the moderate forereef stratum. Coral cover was low (~ 5%) and were comprised of *Porites lobata*. Rubble, sand, turf algae and the algae *Macrodictyon* spp. made up the remaining low complexity substrate. The fish assemblage here was unremarkable; *Thalassoma duperrey* was the most abundant species, with the only moderate-to-large fish counted being several *Chloruru perspicillatus*.

PHR-185      9/23/08  
N 27°56.492   W 175°51.780  
Depth: 21 m

This site is located in the northwestern forereef of Pearl and Hermes Atoll. It was established by the REA fish team as a new sampling location in the deep forereef stratum. Coral cover at this site was very low and consisted primarily of sparse patches of encrusting *Porites lobata*. Turf algae was abundant in this high complexity spur-and-groove area, and crustose coralline algae was commonly seen. *Halimeda* was found in small patches. One whitetip reef shark and 10 ulua were counted; off transect a single jobfish (*Aprion virescens*) made an appearance, as did the Hawaiian morwong. Parrotfish – recruit, juvenile, and adult *Chlorurus sordidus* and *Scarus dubius* – were relatively common, though overall fish diversity and abundance were low. The wrasse *Thalassoma duperrey* was also recorded often on the transect.

PHR-188  
N 27° 48.345 W 175° 45.373  
Depth: 19 m

This site is located on the southeast forereef. It was established by the REA fish team as a new sampling location in the deep forereef stratum. Visibility was very good at approximately 100 feet, but a current moving at approximately 1.2 knots in the southwesterly direction made surveying difficult. A 200-cm *Carcharhinus galapagensis* was seen on the surface upon arrival at the site, and a few *Aprion virescens* were present off transect. Substrate is flat with minimal relief and approximately 80 percent covered in *Dictospheria*. Fish abundance and diversity were low, with *Thalassoma duperrey*, *Parupeneus multifasciatus*, and *Centropyge potteri* being the most common species.

PHR-191      9/24/08  
N 27° 49.866 W 175° 47.966  
Depth: 0.5 m

This site was in the eastern lagoon of Pearl and Hermes Atoll. It was established by the REA fish team as a new sampling location in the shallow lagoon stratum. The first transect had 30 % coral cover with *Porites compressa* as the dominant coral species. Sixty percent of the hard substrate was covered by *Dictosperia* algae. The second transect was rubble covered by *Dictosperia*, *Halimeda*, and turf, with scattered colonies of *Pocillopora damicornis*, and *Fungia* spp. at about 1% coral cover. This area has high relief for small juvenile fish and supported lots of juvenile *Gomphosus varius*, *Thalassoma duperrey*, and juvenile scarids. Adjacent to this site, the reef flat dropped off into sand, where there were large *Naso unicornis*, *Bodianus bilunulatus*, and *T. ballieui*.

PHR-192      9/22/2008  
N 27°47.738 W 175°52.668  
Depth: 2 m

This site is located in the southwestern lagoon of Pearl and Hermes Atoll. It was established by the REA fish team as a new sampling location in the lagoon shallow stratum. The site had low rugosity and low coral cover. Large rubble mixed with sand dominated the site with an underlying cover of pavement. Live coral consisted of *Pocillopora* species and covered less than 5% of the total transect area. As such, fish diversity and abundance were quite low. The most abundant fishes found included *Thalassoma duperrey* and *Coris venusta* and consisted mostly of juvenile to subadults. No notable fishes were seen off transect.

PHR-194      9/23/2008  
N 27° 54.758 W 175° 51.376  
Depth: 11 m

This site was located in the northern lagoon. It was established by the REA fish team as a new sampling location in the moderate lagoon stratum. *Porites compressa* was the dominant coral with 80% coral cover on *compressa* mounds with sand patches, with high complexity and relief. This site was a patch reef sloping to a sand bottom. Juvenile scarids were the dominant fish at this site.

PHR-177      10/2/08  
N 27° 47.214 W 175° 52.655  
Depth: 4.5 m

This site was located on the southern forereef of Pearl and Hermes. It was established by the REA fish team as a new sampling location in the shallow forereef stratum. The habitat was low flat spurs and shallow grooves with caves and moderate to high relief and complexity. *Pocillopora* spp. was the dominant coral at 30% coral cover. There were two *Caranx ignobilis* at 90 and 100 cm, one *Caranx lugubris*, one *Elagatis bipinnulata*, one *Aprion virescens* at 70 cm, and one *Triaenodon obesus* at 120cm. There were also several knife jaws in the area and a large mixed school of acanthurids; 200 *Acanthurus triostegus* at 15 cm, 30 *A. leucopareius* at 17 cm, and 30 *A. nigrofuscus* at 17 cm, and several *Naso hexacanthus*, off transect.

PHR-174      10/2/08  
N 27 46.607   W 53.777  
Depth: 2.5m

This site was located on the southern backreef of Pearl and Hermes Atoll. It was established by the REA fish team as a new sampling location in the shallow backreef stratum. The habitat was flat with low relief and complexity, with scattered *Pocillopora* heads with 30% coral cover on transect A and 10% on transect B. Turf algae covered some of the area. There were few fishes at this site. No fishes over 20 cm were seen, and small wrasses predominated.

PHR-173      10/2/08  
N 27° 46.920   W 175° 53.344  
Depth: 2.5m

This site was located on the backreef of Pearl and Hermes. It was established by the REA fish team as a new sampling location in the shallow backreef stratum. The habitat was flat with low relief and complexity, with scattered *Pocillopora* heads, dead coral rubble and turf algae. Coral cover was less than 15%, and the *Pocillopora* heads provided structure for small fishes. There were few fishes at this site, and no fishes over 20 cm were seen. Small wrasses predominated.

PHR-198      10/2/08  
N 27° 47.252   W 175° 56.699  
Depth: 15 m

This site was located in the southwestern lagoon. It was established by the REA fish team as a new sampling location in the moderate lagoon stratum. It was a patch reef with no live coral cover. The entire structure was covered with *Dictospheria* spp. and *Halimeda* spp. There was sand, dead coral rubble, and algae on the sides of the structure. The site overall had low relief except for a small dead coral outcropping on transect B with lots of small fish, composed predominantly of *Dascyllus albisella*, and *Chlorurus sordidus*. There was one *Carcharhinus galapagensis* at 6 ft spotted off transect. This site was dominated by algae and sand.

PHR-122      10/2/08  
N 27° 48.523   W 175° 58.759  
Depth: 8.5 m

This site was located in the western lagoon of Pearl and Hermes. It was established by the REA fish team as a new sampling location in the moderate lagoon stratum. The habitat was flat and dominated by *Dictospheria* spp. and dead coral rubble on top of sand. There were very few live *Pocillopora* heads, and coral cover was less than 1%. Transect A was flat with low relief and transect B ran along a wall, giving one side of the transect moderate relief. This site hosted small wrasses and scarids with some acanthurids and pomacentrids. Two *Aprion virescens* at 70 cm were spotted off transect in addition to those counted on the transect. Also a 5-ft *Triaenodon obesus* was sited off transect.

PHR-187 10/3/08  
N 27° 54.357 W 175° 55.103  
Depth: 22 m

This site is located on the northwestern forereef of Pearl and Hermes Atoll. It was established by the REA fish team as a new sampling location in the deep forereef stratum. This spur-and-groove area had low coral cover, primarily *Porites lobata*. The top of the spur where the transects were laid was fairly flat; towards the edge of the dropoff into the sand channel were overhangs and ledges. Most of the fishes seemed to congregate in these more complex areas and not on the transect, although a few large schools of parrotfish did swim through to be counted. Seen off transect were 2 Amberjacks, a large ulua, and a morwong. A few Potter's angelfish were recorded on transect, but were seen in unusually high numbers (in schools of 7–9 individuals) off transect.

PHR-121 10/3/08  
N 27° 53.548 W 175° 55.237  
Depth: 14 m

This site is located in the northwestern lagoon of Pearl and Hermes Atoll. It was established by the REA fish team as a new sampling location in the lagoon shallow stratum. The site was characterized by large bommies and patch reefs, with low to moderate coral cover (25%), comprising primarily *Porites compressa* on the first transect, then turf-covered rocks and rubble on the second. *Fungia* was common, and sparse patches of *Montipora* occurred with the rubble. Fish abundance and diversity were moderate, with large abundances of the parrotfish *Chlorurus perspicillatus* and *C. sordidus* common, as well as *Stegastes fasciolatus* and *Thalassoma duperrey*. No off transect sightings occurred for large fishes.

PHR-116 10/3/08  
N 27° 53.665 W 175° 56.347  
Depth: 13 m

This site is located on the northwestern forereef of Pearl and Hermes Atoll. It was established by the REA fish team as a new sampling location in the moderate forereef stratum. The site had a moderate rugosity composed primarily of rock encrusted with coralline algae. *Halimeda* covered approximately 50% of the site, while coral cover was sparse. Less than 1% each of *Porites lobata* and *Pocillopora* were encountered. While low in coral cover, this site was moderate in diversity. Parrotfish (*Chlorurus perspicillatus*, *C. sordidus*, *Scarus dubious*) dominated the site, but *Ctenochaetus strigosus* was also relatively common. Only two large fishes were seen off transect, both *Aprion virescens*.

### E.3. Benthic Environment

#### E.3.1. Algae

Benthic communities around Pearl and Hermes Reef were dominated by macro- and turf algal functional groups (Table E.3.1.1.). Macroalgae percent cover exceeded percent cover of coral at 10 of 15 sites surveyed, and turf algae cover exceeded coral cover at 11

of 15 sites. A combined total of 21 species of macroalgae were observed (11 chlorophytes, 3 ochrophytes, 7 rhodophytes) from the 15 sites surveyed (Tables E.3.1.2., E.3.1.3.). Individuals of *Microdictyon setchellianum* were the most prevalent species encountered and covered 0% to 74.8% of the substrate across all sites and greater than 8% of the substrate at 10 of the 15 sites (Table E.3.1.3.). Plants often formed a continuous, dense mat over the seafloor, generally were highly colonized with epiphytes and sometimes showed evidence of high grazing activity. *Halimeda distorta* was documented at 2 of the 15 sites surveyed and covered 52.4% of the substrate at site PHR-24, but was a minor component of the algal community at other sites (Table E.3.1.3.). Also, *Halimeda opuntia* covered 42.4% of the substrate at site PHR-23 but was not documented at other sites (Table E.3.1.3.). Crustose coralline red algae was a major component of the benthic community at sites PHR-23 and PHR-R39 where it composed 18% and 31.2% of the substrate, respectively. Also, cyanobacteria accounted for 25.6% of the substrate at site PHR-24, but was a minor component of the benthos at all other sites (Table E.3.1.3.).

Table E.3.1.1.--Percent cover of algal functional groups at long term monitoring sites at Pearl and Hermes Atoll.

Site	Macroalgae	Turf algae	Coralline red algae (crustose + upright)	Cyanobacteria
PHR-22	64.4%	20.4%	0.8%	-
PHR-23	64.0%	15.2%	18.0%	-
PHR-24	64.4%	-	0.8%	25.6%
PHR-26	21.6%	37.2%	6.4%	-
PHR-R26	72.4%	10.0%	0.8%	-
PHR-30	58.4%	28.8%	1.2%	-
PHR-31	14.4%	20.0%	-	0.4%
PHR-R31	-	36.4%	0.4%	-
PHR-32	80.4%	6.0%	-	-
PHR-R32	26.0%	58.8%	2.4%	-
PHR-33	82.4%	12.8%	1.6%	-
PHR-34	16.0%	62.8%	1.2%	-
PHR-R39	23.2%	43.6%	31.2%	0.4%
PHR-R42	83.2%	8.0%	0.8%	-
PHR-R44	22.0%	48.8%	7.2%	-

Table E.3.1.2--Additional species recorded at each site at Pearl and Hermes Atoll during roving diver surveys.

Site	<b>Chlorophyta</b>
PHR-R31, PHR-R39	<i>Caulerpa racemosa</i>
PHR-32, PHR-R44	<i>Caulerpa serrulata</i>
PHR-R39	<i>Codium arabicum</i>
PHR-R39	<i>Dictyosphaeria cavernosa</i>
PHR-24, PHR-31, PHR-33 PHR-R39, PHR-R42	<i>Dictyosphaeria versluysii</i>
PHR-R26, PHR-32, PHR-34 PHR-R39	<i>Halimeda discoidea</i>
PHR-R31	<i>Halimeda distorta</i>
PHR-R42	<i>Halimeda velasquezii</i>
PHR-R31, PHR-34	<i>Microdictyon setchellianum</i>
PHR-R26, PHR-33, PHR-R39, PHR-R42 PHR-R44	<i>Neomeris</i> sp.
PHR-34	<i>Valonia</i> sp.
	<b>Ochrophyta</b>
PHR-R26, PHR-34, PHR-R39, PHR-R44	<i>Dictyota ceylanica</i>
PHR-22, PHR-30, PHR-33	<i>Styopodium flabelliforme</i>
PHR-R32, PHR-33	<i>Turbinaria ornata</i>
	<b>Rhodophyta</b>
PHR-32	<i>Ganonema farinosum</i>
PHR-R39	<i>Gibsmithia hawaiiensis</i>
PHR-33	<i>Jania</i> sp.
PHR-32	<i>Laurencia galtsoffii</i>
PHR-R31, PHR-R32 PHR-R39	<i>Laurencia</i> sp.
PHR-R39	<i>Peyssonnelia</i> sp.
PHR-R44	<i>Spyridea filamentosa</i>

Table E.3.1.3.--Percent cover of macroalgal species at long-term monitoring sites at Pearl and Hermes Atoll. Sum totals for each row equal the percent cover of macroalgae recorded in Table E.3.1.1.

Site	<i>Caulerpa webbiana</i>	<i>Codium arabicum</i>	<i>Codium edule</i>	<i>Dictyosphaeria cavernosa</i>	<i>Dictyosphaeria versluysii</i>	<i>Halimeda discoidea</i>	<i>Halimeda distorta</i>	<i>Halimeda opuntia</i>	<i>Halimeda velasquezii</i>	<i>Microdictyon setchellianum</i>	<i>Neomeris</i> spp.	<i>Dictyota ceylanica</i>	<i>Lobophora variegata</i>	<i>Padina</i> sp.	<i>Styopodium flabelliforme</i>	<i>Turbinaria ornata</i>	<i>Dasya iridescens</i>	<i>Galaxaura</i> sp.	<i>Ganonema farinosum</i>	gelid	<i>Laurencia galtsoffii</i>	<i>Nemastoma</i> sp.	<i>Peyssonnelia</i> sp.	<i>Portieria hornemannii</i>
PHR-22	-	-	-	-	2.8	-	-	-	-	58.0	-	-	-	-	-	-	-	-	3.6	-	-	-	-	-
PHR-23	0.8	2.0	0.4	0.4	0.8	-	-	42.4	4.0	8.8	-	0.4	1.2	-	-	0.8	-	-	-	0.4	-	0.4	1.2	-
PHR-24	-	-	-	-	0.8	6.4	52.4	-	4.4	-	-	-	-	-	-	-	0.4	-	-	-	-	-	-	-
PHR-26	-	0.4	-	1.6	0.8	1.6	-	-	1.6	8.4	-	-	-	-	-	-	-	-	-	-	7.2	-	-	-
PHR-R26	-	-	-	-	0.4	0.4	-	-	7.6	58.4	0.4	-	1.6	0.8	-	-	-	-	0.4	-	2.4	-	-	-
PHR-30	-	-	-	-	0.4	-	-	-	-	30.0	-	-	4.8	-	0.4	-	-	-	5.6	-	17.2	-	-	-
PHR-31	-	-	-	-	0.8	1.2	1.6	-	0.4	10.0	0.4	-	-	-	-	-	-	-	-	-	-	-	-	-
PHR-R31	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PHR-32	-	-	-	0.8	-	-	-	-	-	67.6	0.4	-	-	1.2	10.4	-	-	-	-	-	-	-	-	-
PHR-R32	-	-	-	-	-	-	-	-	2.0	20.8	-	-	-	-	-	-	-	0.4	2.8	-	-	-	-	-
PHR-33	-	-	-	-	0.4	1.2	-	-	0.4	76.0	-	-	3.6	-	-	-	-	-	0.4	-	0.4	-	-	-
PHR-34	-	-	-	-	-	-	-	-	6.0	-	-	-	10.0	-	-	-	-	-	-	-	-	-	-	-
PHR-35																								
PHR-R39	-	-	-	-	-	-	-	-	13.2	0.4	0.4	-	8.8	-	-	-	-	-	-	-	-	-	-	0.4
PHR-R42	-	-	-	-	-	0.8	-	-	0.8	74.8	0.4	-	5.2	0.4	-	-	-	-	0.8	-	-	-	-	-
PHR-R44	-	-	-	-	-	0.8	-	-	20.4	-	-	-	0.8	-	-	-	-	-	-	-	-	-	-	-



## E.3.2. Corals

### E.3.2.1 Coral Populations

LPI surveys indicate that coral cover at REA sites around Pearl and Hermes in 2008 varied with both habitat and region. Mean coral cover was highest inside the lagoon ( $22.4 \pm 11.8\%$ ), moderately low within the backreef ( $11.2 \pm 7.9\%$ ) and lowest on the forereef ( $7.8 \pm 3.2\%$ ).

Coral community structure varied both between and within habitats which partly explains some of the variability in coral cover within habitats. Within the backreef, *Montipora capitata* mounds with encrusting *M. flabellata* were dominant at the northeastern site (PHR-26) while the other backreef sites were dominated by sparse assemblages of *Pocillopora* and *Porites lobata*.

The forereef sites at Pearl and Hermes PHR-34 were mostly dominated by *Porites lobata*, which was dominant in the northern forereef (PHR-R44 and R39) and the southeastern forereef (PHR-33 and -R26). Within the southwestern forereef, PHR-34 exhibited a relatively even community of *Montipora*, *Porites*, *Pocillopora*, and *Leptastrea*. PHR-R42 consisted of mostly *Pocillopora* and *Porites*, with many *Leptastrea* colonies seen as well, although had high percentages of mortality. Interestingly, about 25 meters further west from the site -R42, abundant fields of dominant *Pocillopora* were seen.

The lagoon at Pearl and Hermes covers a vast area encompassing some very different habitats. Habitat types varied from well developed *Porites compressa* reefs (PHR-31) to *Porites* patch reefs (PHR-24 and -23), to less developed patch reefs dominated by sparse *Pocillopora* assemblages and finally patch reefs made of mounding *Montipora capitata* (PHR-31).

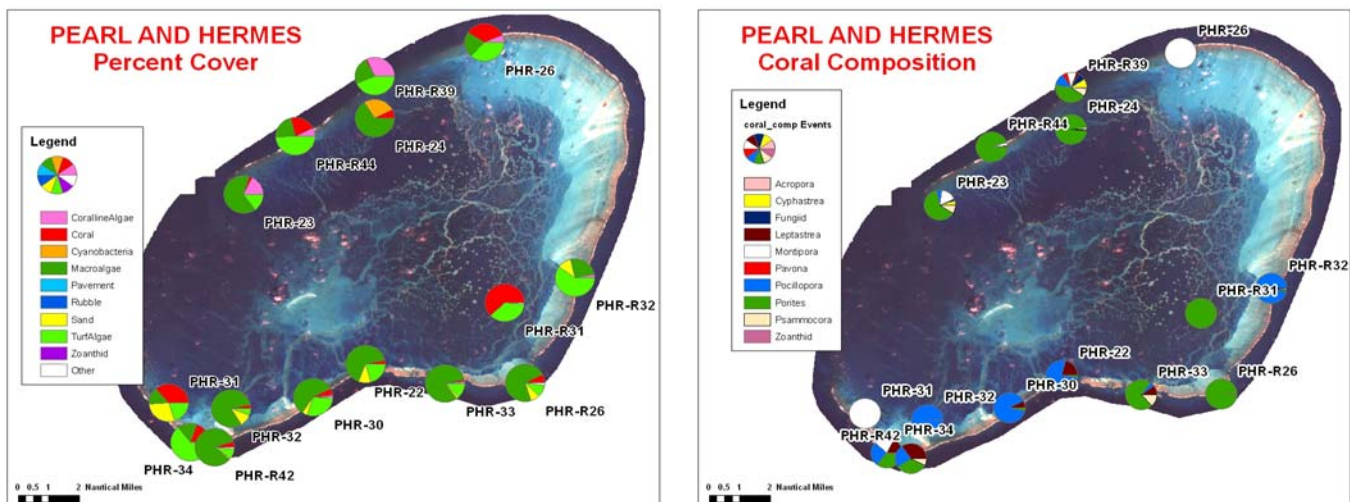


Figure E.3.2.1.1.--Spatial distribution of benthic cover and coral composition for REA sites at Kure in 2008.

Table E.3.2.1.1.--Relative percentage of coral taxon enumerated within belt transects for three habitat strata at Kure in 2008.

Lagoon		Forereef		Backreef	
Taxon	Percent	Taxon	Percent	Taxon	Percent
<i>Porites compressa</i>	67.3	<i>Porites lobata</i>	61.7	<i>Montipora capitata</i>	65.4
<i>Montipora capitata</i>	27.4	<i>Leptastrea purpurea</i>	8.1	<i>Montipora flabellata</i>	19.5
<i>Pocillopora meandrina</i>	3.8	<i>Porites evermanni</i>	7.3	<i>Pocillopora meandrina</i>	11.5
<i>Porites lobata</i>	0.4	<i>Montipora patula</i>	5.8	<i>Leptastrea purpurea</i>	1.5
<i>Pocillopora damicornis</i>	0.3	<i>Pocillopora ligulata</i>	5.6	<i>Pocillopora</i> sp.	0.8
<i>Montipora flabellata</i>	0.3	<i>Pocillopora meandrina</i>	3.7	<i>Pocillopora ligulata</i>	0.3
<i>Psammocora stellata</i>	0.2	<i>Porites compressa</i>	1.6	<i>Porites lobata</i>	0.2
<i>Cyphastrea ocellina</i>	0.1	<i>Montipora capitata</i>	1.5	<i>Porites evermanni</i>	0.2
<i>Pavona varians</i>	0.1	<i>Psammocora stellata</i>	1.4	<i>Montipora patula</i>	0.2
<i>Leptastrea purpurea</i>	0.1	<i>Palythoa</i> sp.	1.0	<i>Pocillopora damicornis</i>	0.1
<i>Porites</i> sp.	0.0	<i>Fungia scutaria</i>	0.5	<i>Porites solida</i>	0.1
<i>Fungia scutaria</i>	0.0	<i>Pocillopora damicornis</i>	0.4	<i>Fungia scutaria</i>	0.1
<i>Pocillopora ligulata</i>	0.0	<i>Cyphastrea ocellina</i>	0.4	<i>Psammocora stellata</i>	0.1
<i>Porites evermanni</i>	0.0	<i>Pocillopora</i> sp.	0.4	<i>Cyphastrea ocellina</i>	0.0
<i>Pocillopora</i> sp.	0.0	<i>Pavona maldivensis</i>	0.2	<i>Porites</i> sp.	0.0
		<i>Pavona duerdeni</i>	0.2		
		<i>Pavona varians</i>	0.2		
		<i>Porites</i> sp.	0.1		
		<i>Porites brighami</i>	0.1		
		<i>Zoanthus</i> sp.	0.0		

### E.3.2.2. Coral Disease

During 2008 REA surveys, there were many examples of compromised coral health conditions. Bleaching was observed in all three reef habitats with *Montipora capitata* and *M. patula* being the most common species affected (Fig. E.3.2.2.1.). In particular, 100% of *M. patula* colonies were found to be bleached in the backreef. Algal interactions, hyperpigmentation, and *Porites trematodiasis* were also observed to affect various coral genera in all reef habitat types (Fig. E.3.2.2.2.). Partial mortality was observed and values are represented in Figure E.3.2.2.3. *Psammocora* colonies were found to exhibit partial mortality at all three habitat types. *Montipora* colonies were found to be almost 50% dead tissue at backreef sites. At forereef sites, *Leptastrea* colonies showed the highest percentage of partial mortality out of the eight genera represented. Finally, at lagoonal sites, *Psammocora*, *Porites* and *Pavona* genera had moderately low percentages of partial mortality.

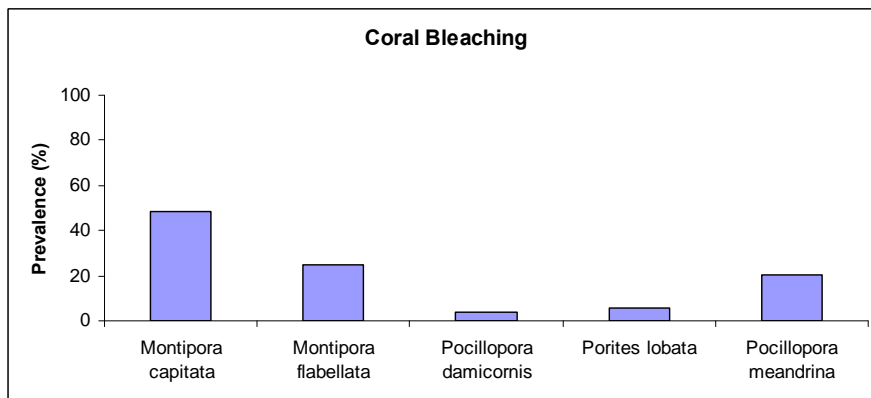
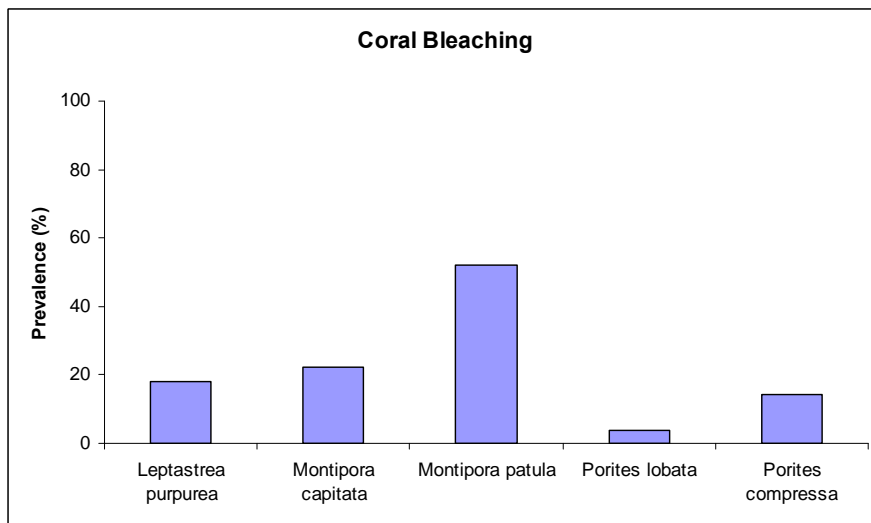
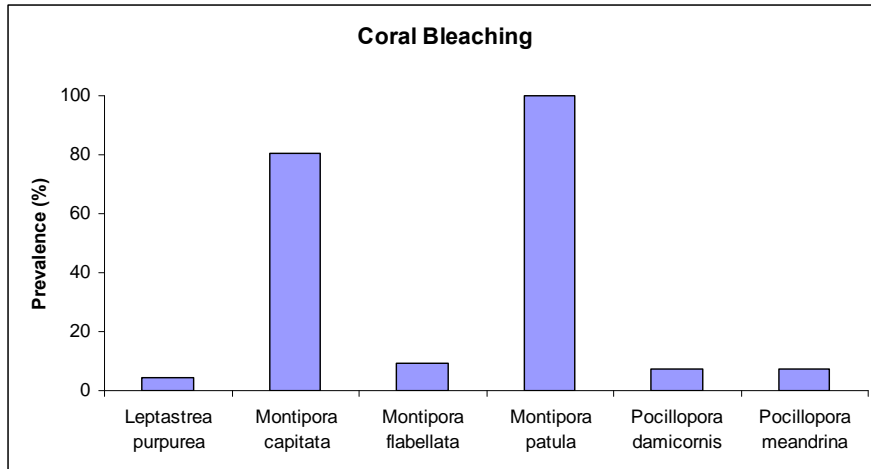


Figure E.3.2.2.1.--Top: Prevalence of bleached colonies for six taxon at Pearl and Hermes backreef sites. Middle: Prevalence of bleached colonies for five coral taxon at Pearl and Hermes forereef sites. Bottom: Prevalence of bleached colonies for five coral taxon at Pearl and Hermes lagoonal sites.

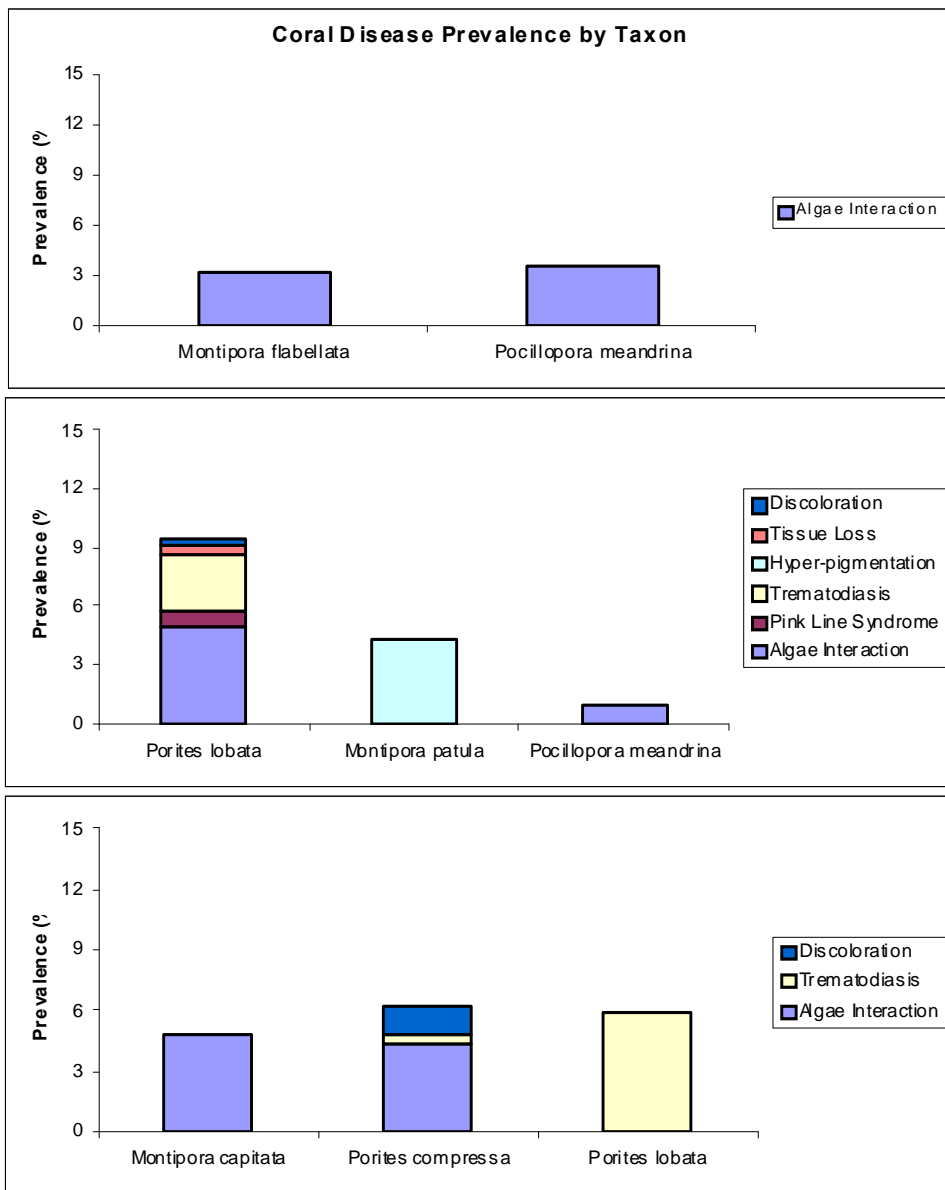


Figure E.3.2.2.2.--Top: Prevalence of coral disease by disease state for two coral taxon at Pearl and Hermes backreef sites. Middle: Prevalence of coral disease by disease state for three coral taxon at Pearl and Hermes forereef sites. Bottom: Prevalence of coral disease by disease state for three coral taxon at Pearl and Hermes lagoonal sites.

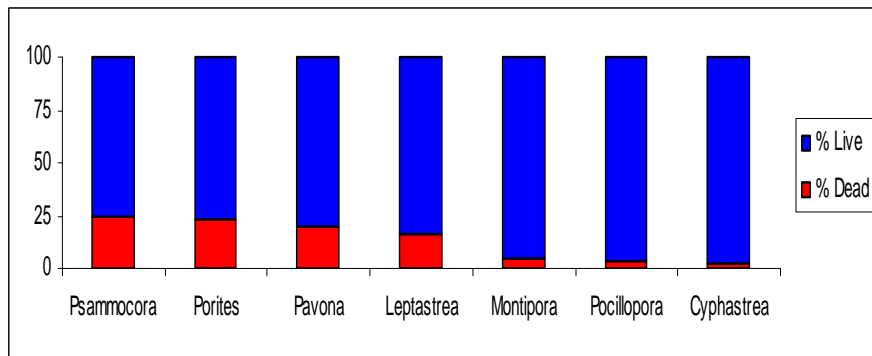
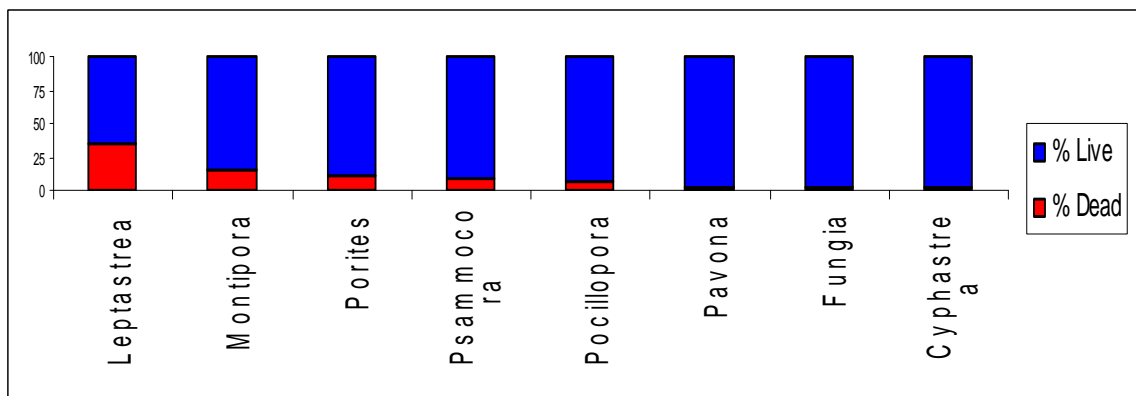
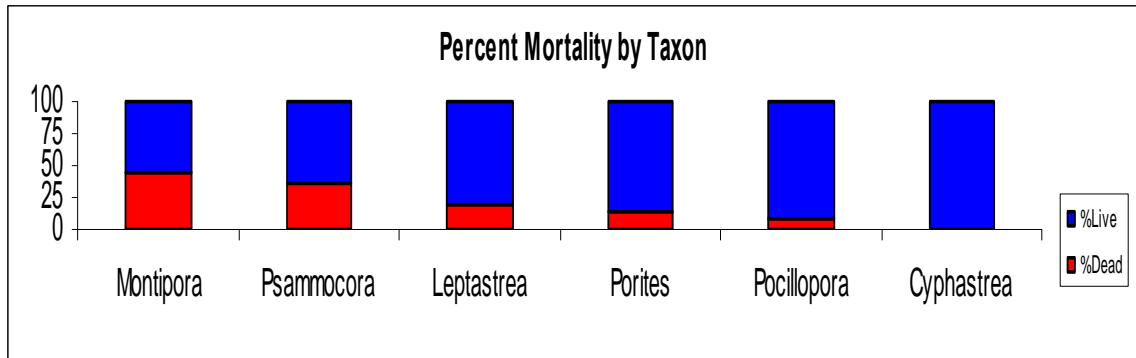


Figure E.3.2.2.3.--Top: Relative percent of dead versus live surface area for six coral genera at Pearl and Hermes backreef sites. Middle: Relative percent dead versus live surface area for eight coral genera at Pearl and Hermes forereef sites. Bottom: Relative percent of dead versus live surface area for seven coral genera at Pearl and Hermes lagoon sites.

### E.3.3. Non-coral Invertebrate Surveys

A total of 7483 individuals of benthic invertebrate target species or taxa group were enumerated from 30 belt transects at 15 sites. The sea urchin, *Echinostrephus aciculatus*, was the most abundant benthic invertebrate in forereef sites ( $n = 6$ ) and *Echinometra mathaei* was the most abundant benthic invertebrate in backreef ( $n = 4$ ) (mean density 6.92 and 5.02/m<sup>2</sup>, respectively). However, both were low at lagoon sites (*E. aciculatus* 0.01/m<sup>2</sup> and *E. mathaei* 0.08/m<sup>2</sup>). The forereef site, PHR-33, had the highest density of *Echinostrephus aciculatus* with 17.35/m<sup>2</sup> and the backreef site, PHR-R30, had the highest density of *E. mathaei* with 12.26/m<sup>2</sup>. Additionally, this backreef site had relatively high densities of coral eating snails, *Coralliophila* sp. (0.44/m<sup>2</sup>), and trapezid crabs (0.20/m<sup>2</sup>). The lagoon site, PHR-23, had relatively high densities of the cliff oyster, *Spondylus* (0.36/m<sup>2</sup>). Although not enumerated, another bivalve, *Arca ventricosa*, was also abundant at this site. Additionally, *A. ventricosa*, was prevalent at the lagoon site, PHR-24. Vermetid snails were widespread on the *Porites compressa* at the lagoon site, PHR-R31. The brittle star was widespread at both PHR-30 and PHR-22 in the backreef. Additionally, the invasive hydroid, *Pennaria disticha*, was prevalent at site PHR-30.

#### E.3.3.1. Urchin Measurements

Figure E.3.3.1.1. reveals the average test diameter of urchins encountered at each site. Only sites where  $\geq 5$  measurements were recorded for a species are represented.

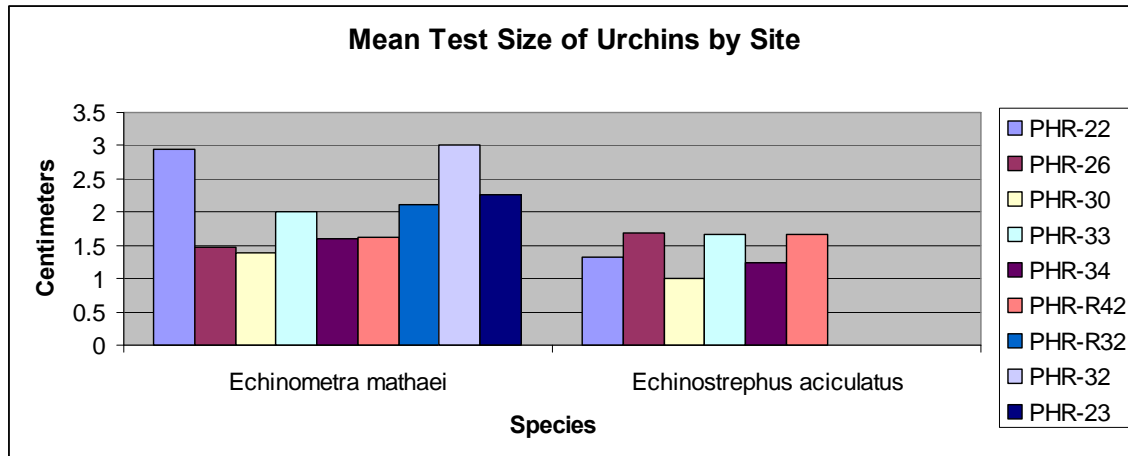


Figure E.3.3.1.1.--Mean test size of urchins by site.

Figure E.3.3.1.2.--reveals the average test diameter of urchins by stratum. Only stratum where  $\geq 5$  measurements were recorded for a species is represented.

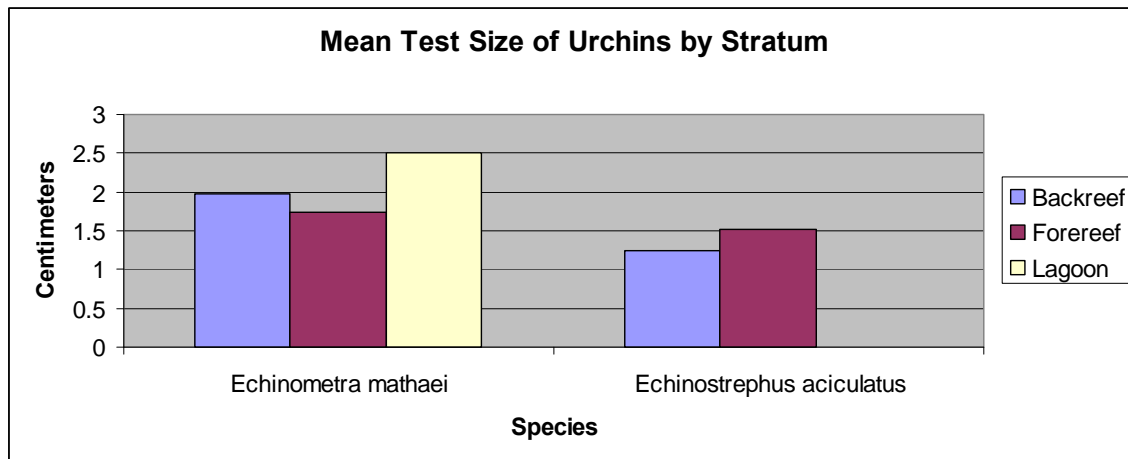


Figure E.3.3.1.2.--Mean test size of urchins by stratum.

#### E.3.3.2. ARMS Deployment

ARMS were deployed at the following REA sites around Pearl and Hermes Atoll. Each site contains three ARMS.

Table E.3.3.2.1. ARMS deployment locations around Pearl and Hermes Atoll.

REA Site	Latitude	Longitude
PHR-R42	27° 45.188 N	-175° 56.926 W
PHR-R33	27° 49.586 N	-175° 47.484 W
PHR-R26	27° 47.150 N	-175° 46.817 W
PHR-33	27° 47.128 N	-175° 49.425 W
PHR-23	27° 52.868 N	-175° 55.967 W

#### E.3.4 Towed-diver Benthic Surveys

The 27 towed-diver benthic habitat surveys of Pearl and Hermes Atoll were conducted along the outlying forereef habitats atoll-wide, along with sections of the backreef located along the south, southwest, north, northeast and east expanses. Lagoonal towed-diver surveys were not conducted due to poor visibility and highly complex reticulated reef structure that would make small-boat piloting hazardous.

The overall averages for substrate composition and macroinvertebrate population densities are illustrated in the tables below (Tables E.3.4.1., E.3.4.2.)

Table E.3.4.1.--Overall benthic habitat composition.

Substrate	Percent Cover (%)	Percent Cover Range (%)
Hard Coral	10.50	0.1 – 50
Stressed Hard Coral	7.05	0 – 62.5
Soft Coral	<1%	0 – 5
Sand	17.88	0 – 100
Rubble	13.27	0 – 100
Macroalgae	34.07	1.1 – 100
Coralline algae	12.60	0 – 62.5

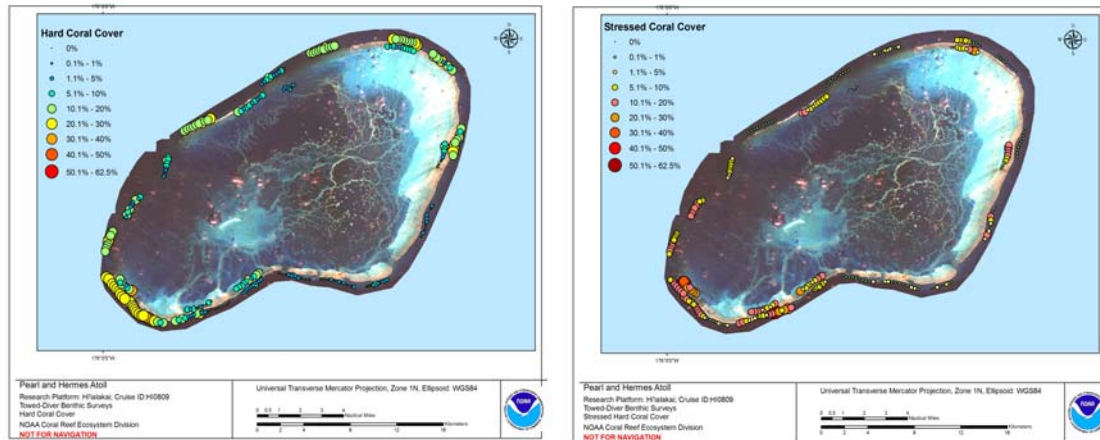
Table E.3.4.2.--Overall macroinvertebrate population densities.

Macroinvertebrate	Density (#/hectare)	Total # Observed
<i>Acanthaster Planci</i> (COTs)	1.89	119
Boring sea urchins	744.7	46,918
Free-living sea urchins	0.86	54
Sea Cucumbers	36.10	2,274

The forereef habitat around Pearl and Hermes Atoll was somewhat delineated by region; however, general forereef benthos composition consisted of a variety of spur-and-groove habitats and continuous reef. The exception was a large, flat plain of pavement covered by an almost monotypic swath of *microdictyon setchellianum* along the south coast of Pearl and Hermes from the vicinity of Seal Kittery to Southeast Island, which faded into sand and rubble flats before returning to spur and groove along the windward side. Backreef habitat consisted of a mix between sand and rubble flats, stretches of pavement and pavement reef, and continuous reef.

Hard coral cover averaged around 10.5% (range 0–50%), with the highest coral cover recorded in 26.18% in the southwest forereef habitats extending west of Seal Kittery. Coral cover peaked at 40.1–50% near the southwestern tip of the atoll, consisting primarily of continuous reef/spur-and-groove habitat. The most prevalent coral genera/species included *Porites lobata*, *Pocillopora* sp., *Montipora* sp., and *fungia*. Of particular interest were the localized increases in coral diversity (esp. along the spur walls) and sightings of isolated *Acropora* colonies.

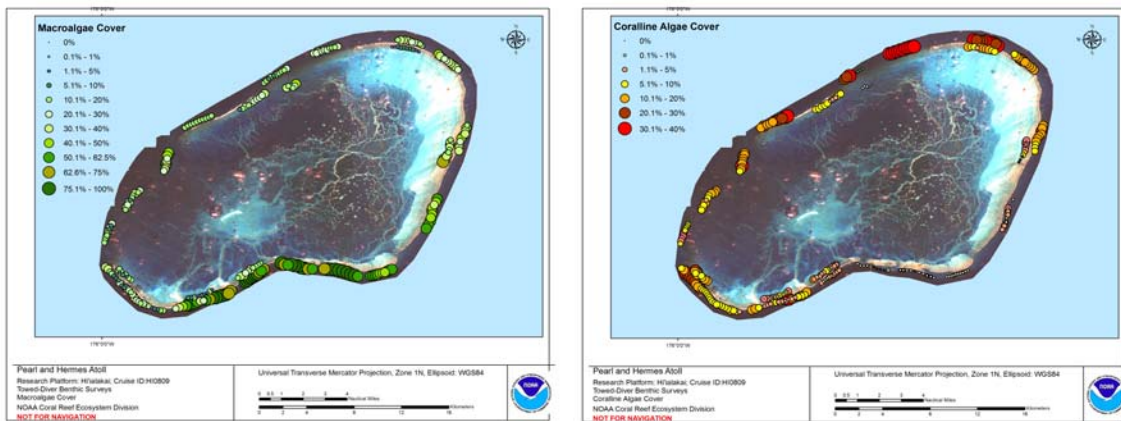




Figures E.3.4.1. and E.3.4.2.--Hard coral and stressed coral cover.

Coral stress averaged 7.05% (range 0–62.5%), with coral stress associated with paling/bleaching or COT predation. The highest coral stress was found along the backreef survey in the vicinity of Seal Kittery, which recorded high levels of coral stress (paling/bleaching, up to 62.5%) in both *Montipora* (capitata) and *Pocillopora* colonies.

Macroalgae cover averaged 34.07% (range 1.1–100%) island wide, and was generally highest along the southern forereef habitat where *Microdictyon setchellianum* monotypic reef was prevalent. Coralline algae averaged 12.60% (range 0–62.5%), with the highest cover noted in the northwest (consistently between 30.1 and 40%), characterized by higher complexity spur-and-groove reef and low coral diversity.



Figures E.3.4.3. and E.3.4.4.--Macroalgae and coralline algae cover.

A total of 199 COTS were encountered during the pooled towed-diver surveys at Pearl and Hermes, with an overall average of 1.89 COTS/ha<sup>-1</sup>. COTS counts were highest along the southwestern forereef habitat, with 34 COTS counted during one survey. Predation of *Pocillopora meandrina* and *Pocillopora damicornis* was evident in terms of elevated coral stress numbers recorded (coupled with potential stress caused by faded/bleached corals). COTS numbers were generally low, during all other towed-diver surveys around Pearl and Hermes. Boring sea urchin densities averaged ~745/ ha<sup>-1</sup> and

were highest during a towed-diver survey along the southern forereef, with 6/10 5-minute time segments (~ 200-meters length) recording > 1001 individuals. Free urchins were relatively uncommon at 0.86 urchins/ha<sup>-1</sup>, with the highest number of individuals (33) also recorded during the southern forereef towed-diver survey. Finally, sea cucumber populations averaged around 36/ha<sup>-1</sup>, with the highest numbers encountered (523) encountered during a towed-diver survey of the northern backreef approximately 5 kilometers to the northwest of North Island.

#### E.4 Fish

##### E.4.1 REA Fish Surveys

###### *Belt transect data*

During the survey period, 91 belt transect surveys were conducted at 38 sites around Pearl and Hermes Reef. Jacks (Carangidae) were the largest contributor to total biomass with 32.88 kg 100 m<sup>-2</sup>. Parrotfish (Scaridae) were the second largest contributor to total biomass with 10.18 kg 100 m<sup>-2</sup>, followed by Surgeonfish (Acanthuridae) at 7.18 kg 100 m<sup>-2</sup>. (Table E.4.1.1.).

###### *Overall observations*

A total of 122 fish species were observed during the survey period by all divers. The average total fish biomass at the sites at Pearl and Hermes Atoll during the survey period was 15.49 kg 100 m<sup>-2</sup> for the belt transect surveys (Table E.4.1.2.).

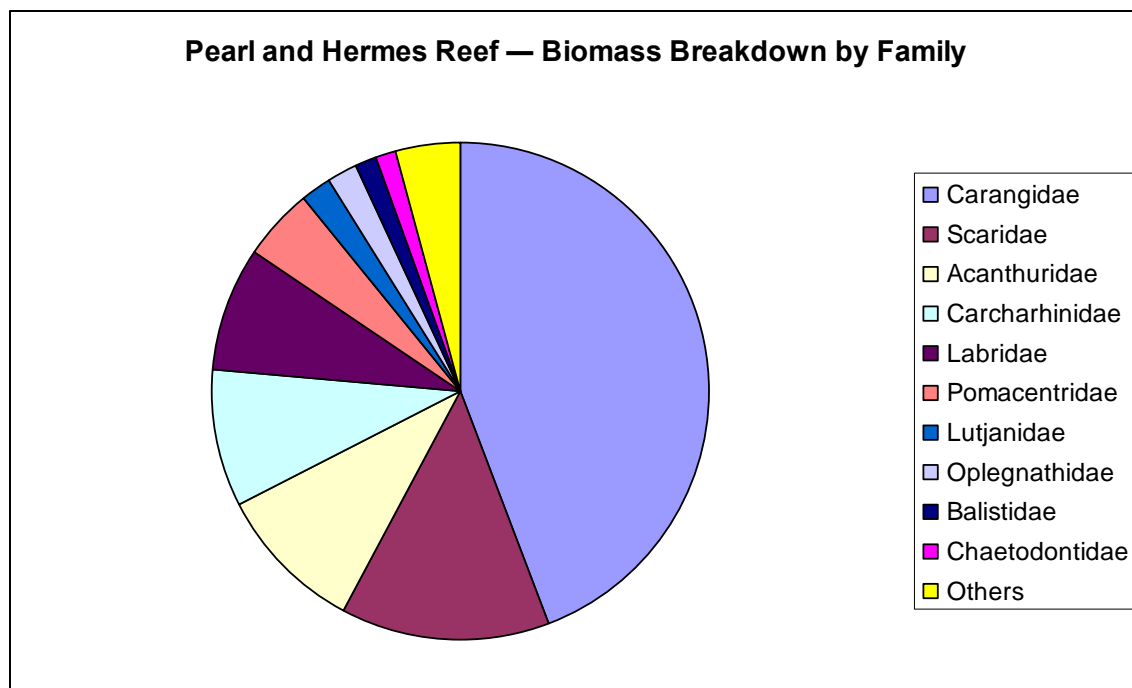


Figure E.4.1.1. --Total fish biomass composition by family.

**Table E.4.1.2.--Coral reef fish biomass (kg 100 m<sup>-2</sup>) by family at sites around Pearl and Hermes Reef.**

Stratum – Depth	Site	Total	Acanth.	Carangid	Carchar.	Chaetod.	Holocen.	Labrid	Lutjanid	Opleg.	Pomacen.	Scarid	Others
Backreef – Shallow	PHR-173	0.91	0.04					0.82			0.02		0.03
	PHR-174	0.34	0.05					0.24					0.05
	PHR-30	0.15	0.00					0.15					0.00
	PHR-R32	0.23	0.01			0.01		0.20			0.01	0.00	0.01
Forereef – Deep	PHR-185	44.69	0.35	31.51	6.44	0.03	0.11	1.33			0.47	4.12	0.33
	PHR-187	4.51	0.23			0.07	0.05	0.79	0.78		0.69	1.52	0.38
	PHR-188	7.49	5.36			0.12		0.83			0.09		1.09
Forereef – Mid	PHR-115	22.35	0.54	17.74				0.72			0.41	2.78	0.17
	PHR-116	14.92	1.26			0.06	1.06	0.82	1.46		0.18	8.58	1.49
	PHR-117	19.08	1.76	14.62				0.79			0.26	1.36	0.28
	PHR-118	20.84	0.74	12.01		0.10	0.22	0.86	2.43		1.48	0.26	2.74
	PHR-179	10.55	2.64			0.07		0.49	0.61		0.43	6.02	0.30
	PHR-181	10.52	0.55	6.44			0.23	0.72	0.46		0.41	1.61	0.10
	PHR-183	31.19	5.51	20.30		0.72		1.66			0.59	1.14	1.25
	PHR-184	3.93	0.40			0.12		0.67			0.75	1.44	0.54
	PHR-33	8.49	0.59	5.22		0.24		0.74			0.16	0.16	1.38
	PHR-34	43.24	0.56	21.48		0.14	2.44	1.10	1.96		10.19	2.15	3.23
	PHR-R26	6.59	1.28			0.20	0.30	1.15	1.05		1.00	0.53	1.08
	PHR-R39	15.22	2.41	6.87		0.04	0.17	0.70	0.31		0.39	3.61	0.72
	PHR-R42	5.00	2.02			0.53		0.75			0.31		1.38
	PHR-R44	182.73	0.11	176.19	1.46	0.02	0.11	0.52			2.37	1.43	0.51
Forereef – Shallow	PHR-175	6.97	0.76	1.06		0.06		0.42			0.76	2.31	1.60
	PHR-176	19.71	4.25		6.80	0.16		4.85			0.28	2.96	0.41
	PHR-177	13.16	2.96	0.12		0.83		2.31		4.18	1.95	0.05	0.77

<b>Table E.4.1.2.--Coral reef fish biomass (kg 100 m<sup>-2</sup>) by family at sites around Pearl and Hermes Reef.</b>													
<b>Stratum – Depth</b>	<b>Site</b>	<b>Total</b>	<b>Acanth.</b>	<b>Carangid</b>	<b>Carchar.</b>	<b>Chaetod.</b>	<b>Holocen.</b>	<b>Labrid</b>	<b>Lutjanid</b>	<b>Opleg.</b>	<b>Pomacen.</b>	<b>Scarid</b>	<b>Others</b>
Lagoon – Mid	PHR-119	6.35			2.19	0.33		0.38			0.23	3.21	0.00
	PHR-122	8.00	0.00	3.78		0.14	0.05	0.70	2.97		0.15	0.13	0.06
	PHR-194	8.41	0.83		4.04	0.30	0.21	0.22			0.11	2.49	0.22
	PHR-198	7.61		6.87		0.10	0.02	0.23			0.15	0.21	0.03
	PHR-24	8.31	0.34	2.67		0.21	0.10	0.64			0.51	3.10	0.74
	PHR-31	3.75	0.03			0.30	0.10	0.59			1.28	0.74	0.69
	PHR-R31	4.72	0.00			0.04	0.03	0.29				4.33	0.03
Lagoon – Shallow	PHR-121	8.34	0.83			0.22	0.18	1.45			0.79	4.84	0.03
	PHR-191	6.57	1.77			0.01		1.33			0.58	2.85	0.03
	PHR-192	0.39	0.05					0.25			0.03		0.05
	PHR-22	0.04	0.00					0.03					0.01
	PHR-23	27.12	2.93	0.14	8.62	0.86	3.10	1.54	1.33		0.75	5.28	2.58
	PHR-26	5.36	0.19			0.18		1.38			0.68	2.89	0.04
	PHR-32	0.74				0.08		0.48			0.09	0.06	0.04
<b>Average</b>		<b>15.49</b>	<b>1.18</b>	<b>20.44</b>	<b>4.93</b>	<b>0.21</b>	<b>0.50</b>	<b>0.87</b>	<b>1.34</b>	<b>4.18</b>	<b>0.84</b>	<b>2.33</b>	<b>0.64</b>

#### E.4.2 Towed-diver Fish Surveys

During the 2008 RAMP mission, the CRED Towboard team completed 27 surveys at Pearl and Hermes Atoll covering 63 km (63 ha) of ocean floor (Table E.4.2.1.). Mean survey length was 2.3 km with a maximum length of 3.1 km and a minimum of 1.3 km. Mean survey depth was 10.3 m with a maximum depth of 16.3 m and a minimum of 1.2 m in the backreef. Mean temperature on these surveys was 27.3 °C with a maximum temperature of 27.9 °C and a minimum of 26.8 °C.

Table E.4.2.1.--Survey statistics for towboard sampling during HI-08-09.

Island/Atoll/Reef	#	Length (km)					Depth (m)				Temperature (°C)			
		Sum	Mean	Max	Min	SD	Mean	Max	Min	SD	Mean	Max	Min	SD
Kure	14	32	2.3	2.7	1.8	0.02	8.2	16.5	0.9	5.9	26.8	27.3	25.5	0.4
Midway	16	39	2.4	3.2	1.9	0.03	9	16.9	0.7	5.9	27.2	28	26.9	0.3
Pearl & Hermes	27	63	2.3	3.1	1.3	0.03	10.3	16.3	1.2	5.2	27.3	27.9	26.8	0.3
Lisianski	12	24.7	2.1	2.3	1.7	0.02	10	14.2	1.6	3.9	28	28.2	27.8	0.1
Laysan	5	11.5	2.3	2.5	2.1	0.01	11.8	13.6	9.2	1.5	27.9	28	27.8	0.1
Maro Reef	11	23.4	2.1	2.4	1.7	0.01	13.3	16.5	9.5	1.8	28.2	28.4	27.9	0.1
French Frigate	26	56.5	2.2	2.9	1.4	0.03	11.5	17.1	1.8	4.5	27.6	28.3	26.9	0.2

Eight hundred thirty-three individual large-bodied reef fish (> 50 cm TL) of 24 different species were encountered at Pearl and Hermes Atoll (Table E.4.2.2.). Overall numeric density for this class of reef fishes was 0.13 #/100 m<sup>2</sup> (13.21 #/ha) with a biomass density of 0.90 kg/100 m<sup>2</sup> (0.09 t/ha). Numeric density was dominated by *Naso unicornis* which was encountered in large schools in the shallow backreef areas on the south side of the atoll. Biomass density was dominated by *Caranx ignobilis* which was seen individually or in small schools of 2–5 individuals all around the atoll, but in higher densities again along the southern margin.

Overall, Acanthurids contributed 43% of the overall numeric density while Carangids contributed 28% and Lutjanids 19% (Fig. E.4.2.1.). Biomass densities were dominated by Carangids (40%) followed by Carcharhinids (21%), Acanthurids (18%) and Lutjanids (17%) (Fig. E.4.2.2.).

Numeric and Biomass densities for large bodied reef fish were higher on the forereef compared to the backreef (Fig. E.4.2.3.). Biomass appears to be clustered in the southwestern portion of the atoll, with relatively low levels along the northwestern and eastern portions of the forereef. Large schools of *Naso unicornis* were encountered in the backreef along the southern portion of the atoll, particularly along a rocky ledge which extended in an east-west direction and emerged approximately 1 meter from the neighboring sand/rubble flats.

Table E.4.2.2.--Species numeric and biomass density for large-bodied reef fish (> 50 cm TL) observed at Pearl and Hermes Atoll during 2008 CRED towed-diver surveys

Species	#	#/100m2	#/ha	Biomass (kg)	kg/100m2	t/ha
Aetobatus_narinari	1	0.0002	0.0159	10.7362	0.0017	0.0002
Aprion_virescens	154	0.0244	2.4429	802.9117	0.1274	0.0127
Aulostomus_chinensis	3	0.0005	0.0476	0.5892	0.0001	0.0000
Carangoides_ferdau	4	0.0006	0.0635	13.7938	0.0022	0.0002
Carangoides_orthogrammus	10	0.0016	0.1586	26.8734	0.0043	0.0004
Caranx_ignobilis	75	0.0119	1.1897	1322.3722	0.2098	0.0210
Caranx_melampygus	104	0.0165	1.6498	268.0905	0.0425	0.0043
Carcharhinus_amblyrhynchos	1	0.0002	0.0159	46.3606	0.0074	0.0007
Carcharhinus_galapagensis	3	0.0005	0.0476	200.6000	0.0318	0.0032
Chlorurus_perspicillatus	11	0.0017	0.1745	28.0500	0.0044	0.0004
Coris_flavovittata	1	0.0002	0.0159	4.4000	0.0007	0.0001
Elagatis_bipinnulata	1	0.0002	0.0159	0.1496	0.0000	0.0000
Fistularia_commersonii	2	0.0003	0.0317	0.1508	0.0000	0.0000
Gymnothorax_flavimarginatus	1	0.0002	0.0159	2.0047	0.0003	0.0000
Manta_birostris	1	0.0002	0.0159	1049.6000	0.1665	0.0167
Monotaxis_grandoculis	16	0.0025	0.2538	50.0922	0.0079	0.0008
Naso_hexacanthus	135	0.0214	2.1415	286.3559	0.0454	0.0045
Naso_unicornis	211	0.0335	3.3471	549.0585	0.0871	0.0087
Oplegnathus_punctatus	26	0.0041	0.4124	68.6622	0.0109	0.0011
Pseudocaranx_dentex	27	0.0043	0.4283	58.5499	0.0093	0.0009
Scomberoides_lysan	1	0.0002	0.0159	1.0036	0.0002	0.0000
Scombrid_sp	10	0.0016	0.1586	27.0368	0.0043	0.0004
Seriola_dumerili	12	0.0019	0.1904	124.1719	0.0197	0.0020
Triaenodon_obesus	23	0.0036	0.3649	725.4061	0.1151	0.0115
Grand Total	833	0.1321	13.2140	5667.0198	0.8990	0.0899

**Numeric Density Contribution by Family for Large-Bodied Reef Fish (>50cmTL) observed at Pearl & Hermes During 2008 CRED Towed-Diver Surveys**

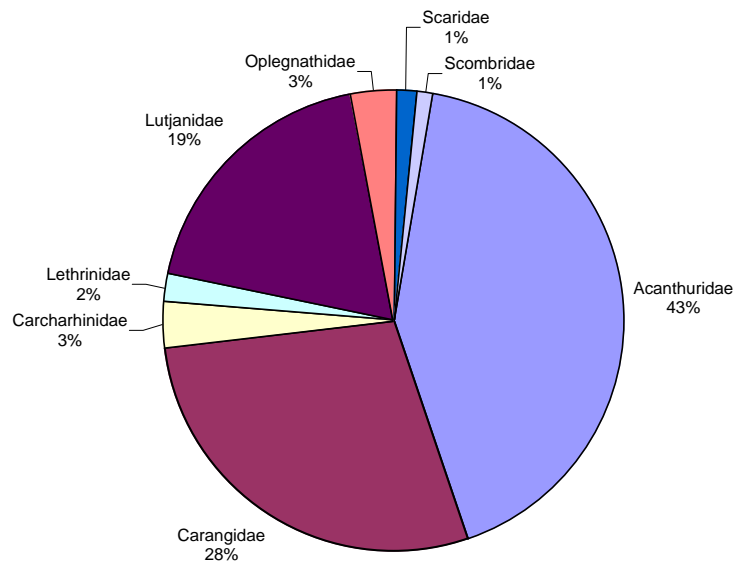


Figure E.4.2.1.--Numeric density by family.

**Biomass Density Contribution by Family for Large-Bodied Reef Fish (>50cmTL) observed at Pearl & Hermes During 2008 CRED Towed-Diver Surveys**

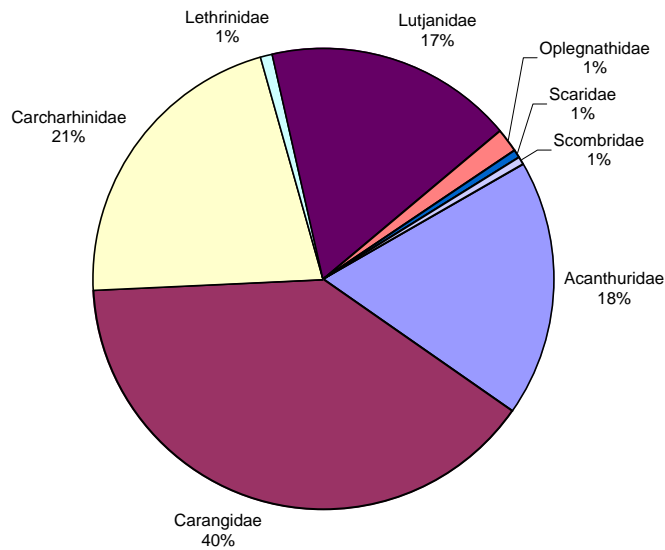


Figure E.4.2.2.--Biomass density by family.

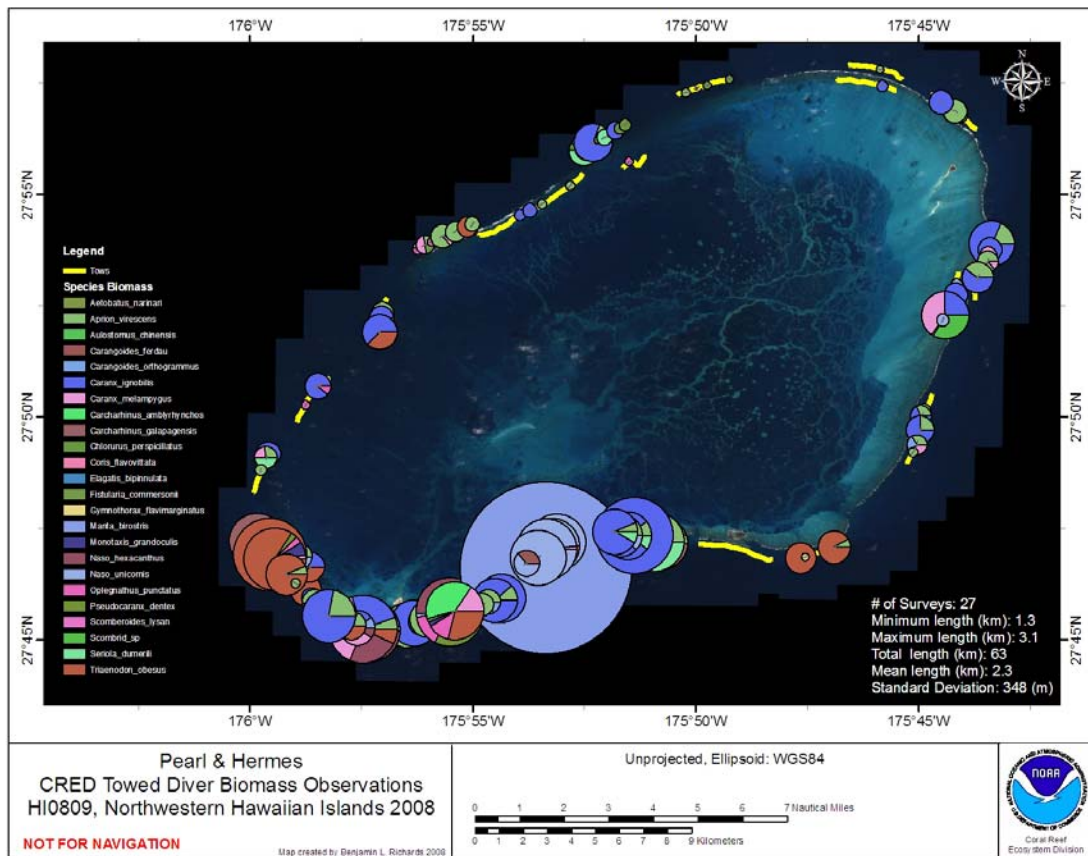


Figure E.4.2.3.--Geographic distribution of biomass around Pearl and Hermes Atoll. Each species is represented by a legend color. Diameter of pie chart is proportional to total biomass of all species encountered on the underlying survey.

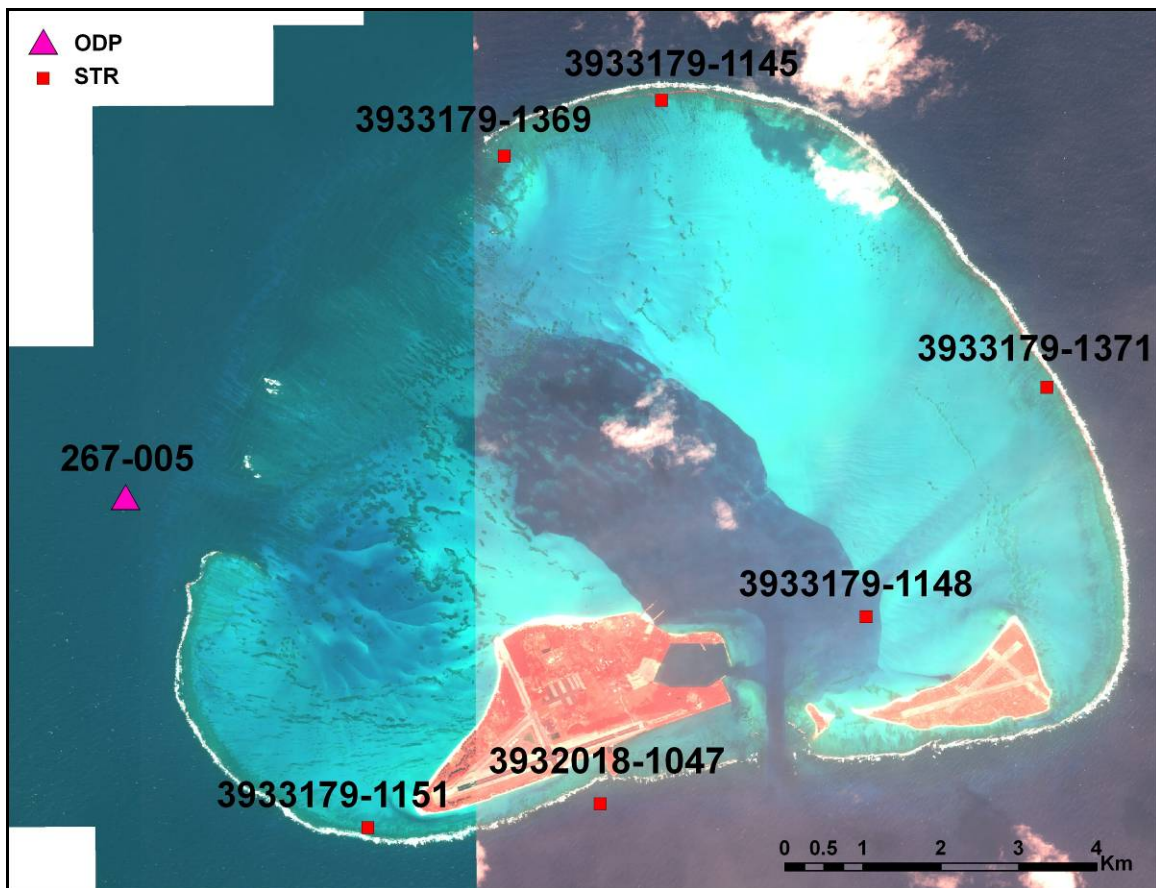


## Appendix F: Midway Atoll

### F.1. Oceanography and Water Quality

Moorings (Fig. F.1.1., Table F.1.1.)

At Midway Atoll during HI0809, six subsurface temperature recorders (STRs) were removed and replaced, one sea surface temperature (SST) buoy was installed in place of one that was lost, and an Ocean Data Platform (ODP, which includes a Sontek Acoustic Doppler Profiler and a Seabird 37 salinity and temperature recorder) was replaced on the west side of the atoll. New mooring deployments at Midway included an ecological acoustic recorder (EAR) site on the southern forereef and a multiple instrument transect designed for a lagoon flushing experiment. This experiment required the deployment of a linear wave and current array at three new mooring sites (deep and mid water wave and tide recorders [WTRs] on the forereef at 20 m and 10 m, respectively and a shallow Aquadopp Current Profiler (AQD) on the backreef at 2 m) positioned parallel to the direction of overall water movement into and out of the lagoon. Data retrieved from these instruments will be used to answer questions of residence time within the atoll, flushing mechanisms and wave decay and friction factors for this reef system.



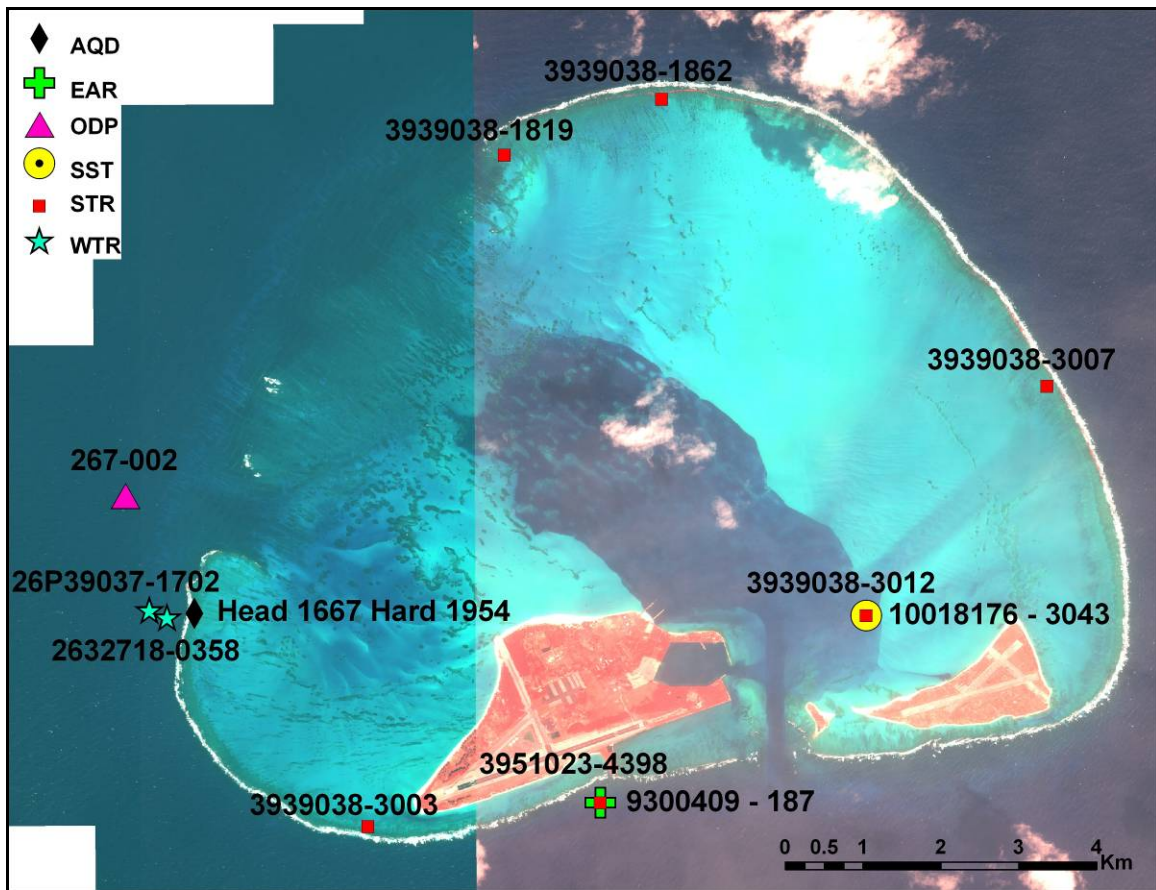


Figure F.1.1.-- Moored Oceanographic instrumentation map for Midway Atoll. Instruments recovered (top) and instruments deployed (bottom).

Table F.1.1.--Moored oceanographic instrumentation table for Midway Atoll.

Instrument	Action	Serial Number	Latitude	Longitude	Data Start	Data End	Depth (m)
SST	Deployment	10018176 - 3043	28.21799	-177.34430	Sep-08	Logging	0.00
STR	Deployment	3939038-3012	28.21799	-177.34430	25-Sep-08	Logging	9.45
SST	Other	10018165	28.21799	-177.34430	Sep-06	Lost At Sea	0.00
STR	Retrieval	3933179-1148	28.21799	-177.34430	15-Sep-06	25-Sep-08	9.45
EAR	Deployment	9300409 - 187	28.19636	-177.37495	25-Sep-08	Logging	14.33
STR	Deployment	3951023-4398	28.19636	-177.37495	25-Sep-08	Logging	14.33
STR	Retrieval	3932018-1047	28.19636	-177.37495	15-Sep-06	26-Sep-08	14.33
STR	Deployment	3939038-3007	28.24449	-177.32342	25-Sep-08	Logging	1.22
STR	Retrieval	3933179-1371	28.24449	-177.32342	15-Sep-06	N/A	1.22
STR	Deployment	3939038-1862	28.27762	-177.36786	25-Sep-08	Logging	0.91
STR	Retrieval	3933179-1145	28.27762	-177.36786	15-Sep-06	25-Sep-08	0.91
STR	Deployment	3939038-1819	28.27116	-177.38602	25-Sep-08	Logging	0.91
STR	Retrieval	3933179-1369	28.27116	-177.38602	15-Sep-06	N/A	0.91
STR	Deployment	3939038-3003	28.19364	-177.40178	25-Sep-08	Logging	1.22
STR	Retrieval	3933179-1151	28.19364	-177.40178	15-Sep-06	N/A	1.22
WTR	Deployment	26P39037-1702	28.21867	-177.42701	1-Oct-08	Logging	18.29
WTR	Deployment	26327180358	28.21783	-177.42495	28-Sep-08	Logging	9.45
AQD	Deployment	Head 1667-1954	28.21826	-177.42181	1-Oct-08	Logging	1.83
ODP	Deployment	267-002	28.23182	-177.42974	27-Sep-08	Logging	30
ODP	Retrieval	267-005	28.23182	-177.42974		29-Sep-08	30

### Preliminary Mooring Results

Three STRs recovered from Midway yielded usable data sets (Fig. F.1.2.). Between September 2006 and September 2008, subsurface water temperatures around Midway fluctuated with seasonal variability typical for these latitudes; lows occurring between January and March ( $\sim 18^{\circ}\text{C}$ ) and highs between August and October ( $\sim 28^{\circ}\text{C}$ ). Shallower instruments showed larger diurnal fluctuations than those in deeper waters due to daily solar heating and cooling.

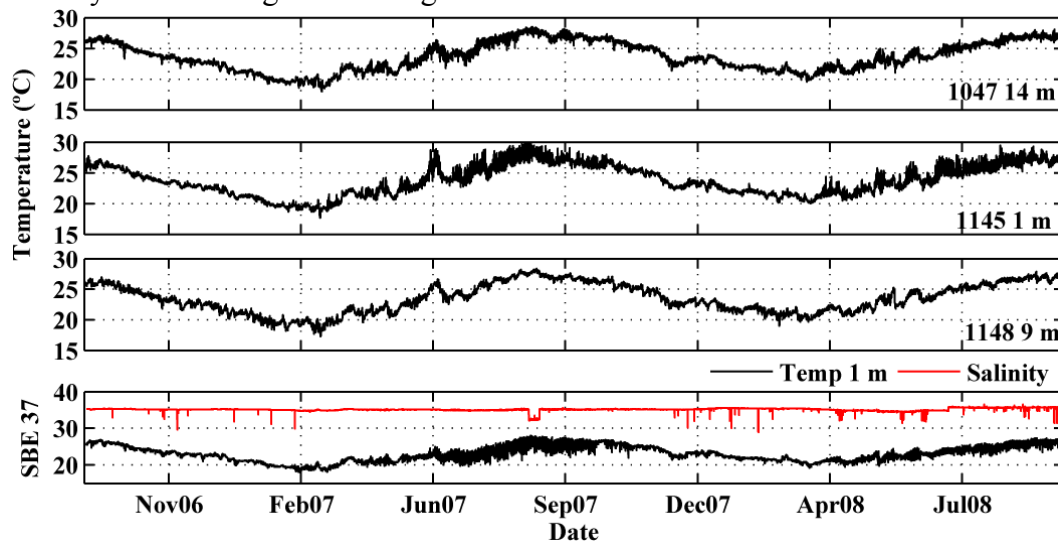


Figure F.1.2.--Temperature and salinity data obtained from three STRs and one SBE37 around Midway Atoll.



## Water Quality:

Seven shallow water conductivity, temperature and depth (CTD) casts were conducted at the 30-m bathymetric contour around Midway Atoll at approximately 2-nautical mile (nmi) intervals using a Seabird 19+ with additional dissolved oxygen (DO) and transmissometer sensors attached (Fig. F.1.3.). All shallow-water CTD casts were conducted on September 28, 2008. Additionally, eight “static” (non-profiling mode) shallow-water CTD casts were conducted in conjunction with the benthic seawater carbonate chemistry sampling.

Discrete water samples, collected concurrently with shallow-water CTD casts, were taken at two of the shallow water CTD sites using a daisy chain of Niskin bottles at 1 m, 10 m, 20 m and 30 m depth bins. Nutrient and chlorophyll samples were processed and stored according to protocol and will be sent out for analysis following the cruise.

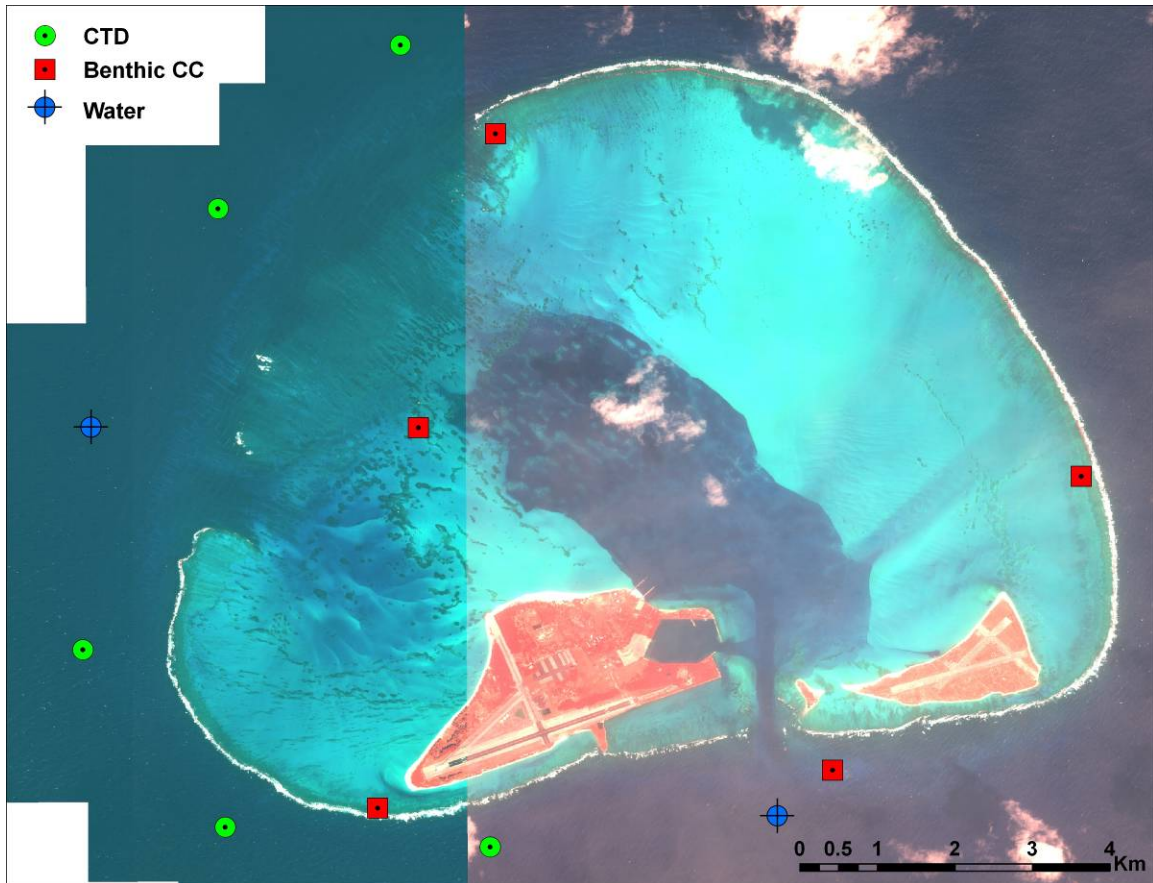


Figure F.1.3.--Shallow-water CTD, water sampling, and benthic carbonate chemistry locations around Midway Atoll.

As of September 29, the ship has hit only one of the three shipboard sites at Midway Atoll. The cast that was sampled was one of the carbonate chemistry transect sites (Fig. F.1.4.). This cast included a CTD profile to 500 m depth, water samples that will be analyzed for chlorophyll and nutrients at the 3 m, 80 m, 100 m, 125 m and 150 m bins, and water samples that will be analyzed for carbonate chemistry (DIC and  $A_T$ ) at the 3 m

and 125 m depth bins. Each of the remaining shipboard casts, to be hit on the way back to Pearl and Hermes, will include a CTD profile to 500 m depth, water samples that will be analyzed for chlorophyll and nutrients at the 3 m, 80 m, 100 m, 125 m and 150 m bins, and water samples that will be analyzed for carbonate chemistry (DIC and  $A_T$ ) at the 3 m and 125 m depth bins. The water samples were and will be processed and stored according to protocol and will be sent out for analysis following the cruise.

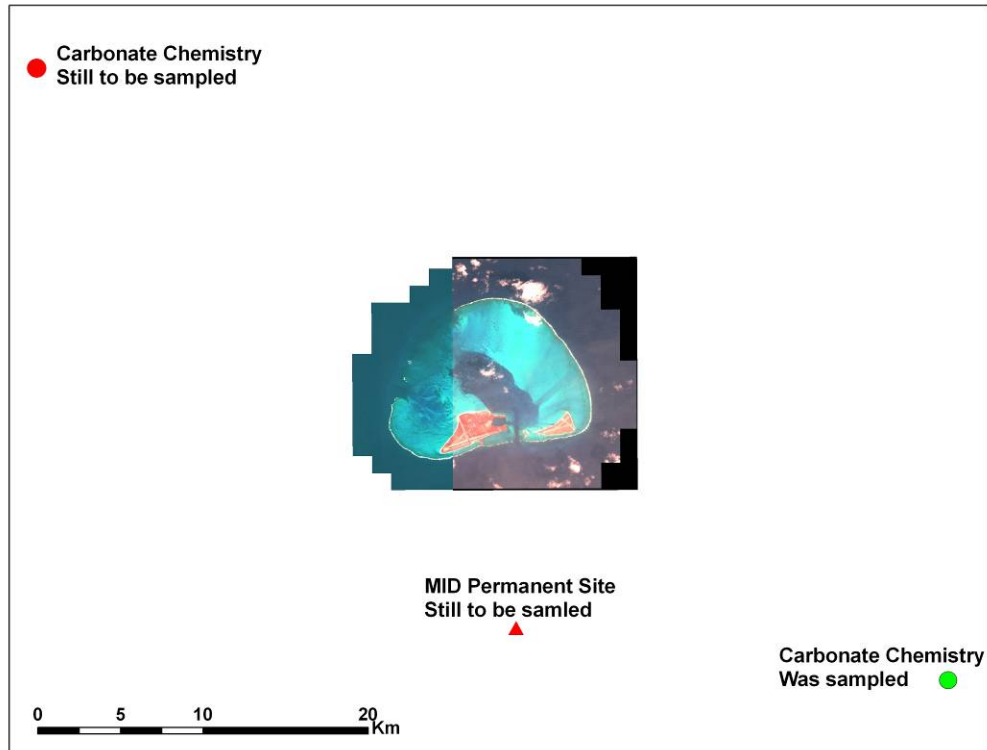
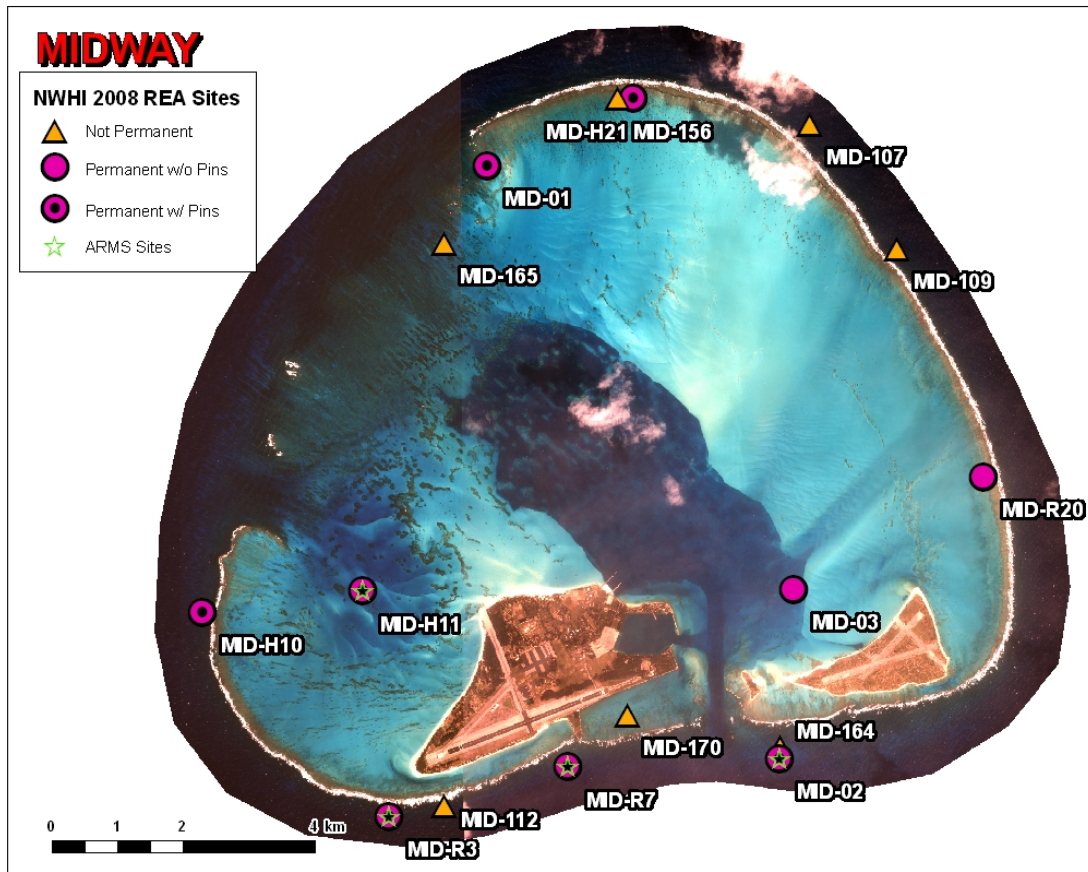


Figure F.1.4.--Permanent shipboard CTD locations near Midway Atoll. Red indicates sites that have not yet been sampled, and green indicates the one site that was sampled.

## F.2. Rapid Ecological Assessment (REA) Site Descriptions



Sixteen REA (Rapid Ecological Assessment) sites were visited by a team of up to 10 scientists around Midway Atoll between September 25 and 28, 2008. Seven of those sites were only surveyed by fish scientists. The site locations are plotted in Figure F.2.1., and the survey dates and efforts are listed in Table F.2.1. Individual site descriptions are included for the following discipline communities: coral and coralline disease, algae, macroinvertebrates, and fish.

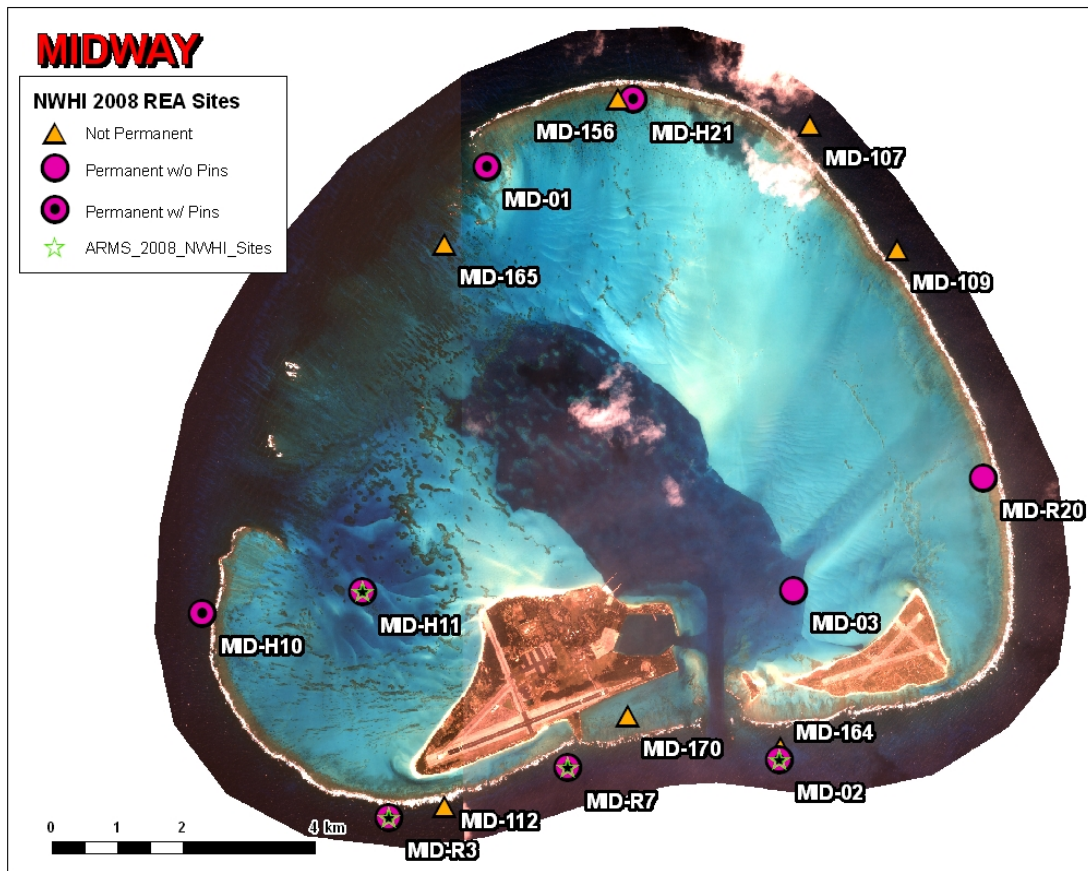


Figure F.2.1.--Midway Atoll 2008 REA site locations.

Table F.2.1.--Midway Atoll survey sites 2008. At each REA site, three 25 m × 4 m belt transects (BLT) were performed by the fish team; at each new site two 25 m × 4 m BLTs were performed; unless otherwise noted. Two 25-m transects were sampled by all benthic teams at each site they visited, unless otherwise noted (see also Table A.2.2).

Site	Date	Depth (m)	Stratum	REA or New Site	Teams	Comments
MID-01	9/26/2008	1	Backreef	REA	Fish, Coral, Algae, Inverts	
MID-02	9/28/2008	12	Forereef	REA	Fish, Coral, Algae	
MID-03	9/28/2008	8	Lagoon	REA	Fish, Coral, Algae, Inverts	
MID-107	9/25/2008	16	Forereef	New	Fish	
MID-109	9/25/2008	14	Forereef	New	Fish	
MID-112	9/26/2008	12	Forereef	New	Fish	
MID-156	9/26/2008	1	Backreef	New	Fish	
MID-164	9/26/2008	11	Forereef	New	Fish	
MID-165	9/26/2008	3	Lagoon	New	Fish	
MID-170	9/26/2008	2	Backreef	New	Fish	
MID-H10	9/25/2008	10	Forereef	REA	Fish, Coral, Algae, Inverts	
MID-H11	9/26/2008	4	Lagoon	REA	Fish, Coral, Algae, Inverts	
MID-H21	9/26/2008	1	Backreef	REA	Fish, Coral, Algae, Inverts	
MID-R20	9/28/2008	1	Backreef	REA	Fish, Coral, Algae, Inverts	
MID-R3	9/25/2008	14	Forereef	REA	Fish, Coral, Algae, Inverts	
MID-R7	9/25/2008	12	Forereef	REA	Fish, Coral, Algae, Inverts	

### Site Descriptions:

September 25, 2008

#### **MID-H10**

*N 28° 12.908', W 177° 25.504'*

Depth range: 10–13 m

Permanent transects installed during this visit. The benthos at this forereef site consisted of highly scoured pavement with extremely low coral cover (2.4%). Colonies were small likely due to the wave energy of the region. *Pocillopora meandrina* was the most abundant coral.



This site was dominated by turf-colonized pavement, *Lobophora variegata*, and small individuals of a species of *Liagora*, and a species of *Padina*. Cyanophytes, crustose coralline red algae, and *Dictyota ceylanica* were also documented on the line point intercept (LPI) survey. *Dictyosphaeria versluysii*, *Galaxaura filamentosa*, a species of *Jania*, and a species of *Martensia* were documented during the Roving Diver survey.

The boring urchins, *Echinostrephus aciculatas* and *Echinometra mathaei*, were abundant. The annelid, *Spirobranchus giganteus*, was common.

This site was relatively depauperate of fish; of the fish seen, damsels (*Chromis hanui* and *C. vanderbilti*) and wrasses (*Thalassoma duperrey* and *Macropharyngodon geoffrey*) were most abundant. The largest fish seen on transect was a single trevally (*Caranx ignobilis*), and, of interest, a single knifejaw (*Oplegnathus punctatus*) was seen off transect.

### **MID-R3**

N 28° 11.42', W 177° 23.972'

Depth range: 13–15 m

Permanent transects. Autonomous Reef Monitoring Systems (ARMS) installed. This forereef site consists of a complex carbonate reef structure with crevasses and overhangs. Coral cover was 4.4% consisting of mostly of highly fissioned *Porites lobata* colonies. A total of seven anthozoan species were seen within the survey area including a single small colony of *Montipora tuescens*.

The benthos at this site was dominated by turf-colonized pavement with a moderate percent cover of *Lobophora variegata*. Crustose coralline red algae was also documented on the LPI survey. A species of *Padina* and *Halimeda velasquezii* were documented during the Roving Diver survey.

The boring urchin, *Echinostrephus aciculatas* dominated the site and *Echinometra mathaei* was common. A single pearl oyster, *Pinctada margaritifera*, was seen.

This site had high fish species diversity with several species of pomacentrids, scarids, goatfishes, and acanthurids. There was a school of 30 *Naso hexacanthus* at 40 cm off transect B, and 10 *Naso brevirostris* at 40 cm. There were approximately 1000 *Chromis ovalis* in the water column and a 60-cm *Aprion virescens* off transect. *C. ovalis* and *C. hanui* were the most abundant fishes present on the transects.

### **MID-R7**

N 28° 11.782', W 177° 22.501'

Depth range: 11–14 m

Permanent transects. ARMS installed. Benthos consisted mostly of barren pavement with low coral cover (8%). *Porites lobata* was the most abundant species with many colonies exhibiting high levels of fission. Other coral species seen within the survey area included: *Psammocora stellata*, *Porites compressa*, *Leptastrea purpurea*, *Palythoa* sp., *Cyphastrea ocellina* and *Pocillopora meandrina*. In addition, a single small colony of

*Montipora capitata* was observed outside of the survey area which appeared to be bleached.

The benthos at this site was dominated by turf-colonized pavement and *Dictyota ceylanica*. Crustose coralline red algae and *Lobophora variegata* were also documented during the LPI survey. *Halimeda velasquezii* was found in very low abundance and was the only additional species documented during the Roving Diver survey.

The boring urchin, *Echinostrephus aciculatus* was abundant and *Echinometra mathaei* was common. The following holothuroids were common: *Holothuria atra*, *H. whitmaei*, and *Actinopyga obesa*. A single live *Spondylus* was seen.

This site was high in fish species diversity with several species of scarids (2 spp.), labrids (12 spp.), acanthurids (8 spp.), pomacentrids (6 spp.), and goatfishes (4 spp.). There were large schools (200 to 400 individuals) of *Chromis hanui* in the water column and just above the substrate on each transect. There were several *Heteropriacanthus cruentatus*, *Goniistius vittatus*, *Genicanthus personatus*, an *Apolomichthys arcuatus*, and seven *Carcharhinus galapagensis* off transect. When we left the site, the benthic team reported 30–40 *C. galapagensis* at 4 to 5 ft in the water column on their safety stop.

#### **MID-107**

N 28° 16.444', W 177° 20.513'

Depth: 16 m

This site is located in the northeastern forereef of Midway Atoll. It was established by the REA fish team as a new sampling location in the moderate forereef stratum. This site was composed of large spur-and-groove sections of pavement reef. The pavement was predominantly devoid of coralline algae, with only sparse patches of turf algae covering the bare rock. Less than 1% of *Pocillopora* and *Porites lobata* was found, with most of the *Pocillopora* colonies dead. Abundance of fishes was low, but diversity was moderate. The most abundant species included *Stegastes fasciatus* and *Thalassoma duperrey*. Off transect sightings included large schools of Kyphosids (all three species) and a few observations of *Aprion virescens*. Eight *Oplegnathus punctatus* were seen, including one *O. fasciatus*. The first sighting of *Evistas acutirostris* was seen for this trip, as well as large *Parupeneus porphyreus*.

#### **MID-109**

N 28° 15.54', W 177° 19.796'

Depth: 14 m

This site is located in the northeastern forereef of Midway Atoll. It was established by the REA fish team as a new sampling location in the moderate forereef stratum. The site was composed of large spur-and-groove patches composed entirely of pavement substrate and covered with sparse patches of turf algae and silt/sand. Coral cover was extremely low, with approximately 5% *Pocillopora* and less than 1% *Porites lobata*. Urchins were common, and three crown-of-thorns starfish were observed outside the transect boundaries. The site was relatively devoid of large fish with the exception of a few large parrotfish off transect. A moderate school of *Acanthurus olivaceus* and *Chromis ovalis*

were seen in the distance. Diversity and abundance of fish on transect were low, with the most common fishes being *Paracirrhites arcatus* and *Thalassoma duperrey*.

September 26, 2008

#### **MID-H21**

N 28° 16.641', W 177° 21.967'

Depth range: 1–2 m

Found permanent transects and took a new more accurate global positioning system (GPS) waypoint. Coral cover was moderately high (44.4%) dominated by *Montipora flabellata*. *Montipora capitata* colonies exhibited substantial partial mortality with many colonies appearing pale.

This site had a low macroalgal percent cover overall with the algal community dominated by turf algae and *Lobophora variegata*. Crustose coralline red algae, a species of *Galaxaura*, and a species of *Sargassum* were also documented during the LPI survey. *Halimeda velasquezii*, *Turbinaria ornata*, *Microdictyon setchellianum*, a species of *Neomeris*, *Stypopodium flabelliforme*, and *Dictyosphaeria versluysii* were all documented during the Roving Diver survey.

The boring urchin, *Echinometra mathaei*, was the dominant invertebrate. The holothuroids, *Holothuria whitmaei* and *Actinopyga obsea*, and the urchin, *Echinostrephus aciculatus*, were common. Vermetid snails were prevalent.

This site was located in very shallow water just behind the reef crest and dominated by juvenile wrasses, parrotfish and the damselfish *Stegastes fasciolatus*. While rugosity was moderate, fish abundance and diversity at this site were fairly low. No large fishes were observed off transect that were not present within the transect boundaries.

#### **MID-01**

N 28° 16.155', W 177° 23.168'

Depth range: 1–2 m

Found permanent transects which were in extremely shallow water and took a new, more accurate, GPS waypoint. Site had moderately high coral cover (48.4%) dominated by *Montipora flabellata*. *Montipora capitata* colonies exhibited substantial partial mortality with many colonies appearing pale.

This site had a low algal percent cover that was dominated by turf algae and *Laurencia galtsoffii*. *Dictyosphaeria versluysii*, *Lobophora variegata*, and crustose coralline red algae were also documented during the LPI survey. A species of *Neomeris*, a species of *Peyssonnelia*, a species of *Halichrysis*, and *Halimeda velasquezii* were documented during the Roving Diver survey.

The boring urchin, *Echinometra mathaei*, was common. Holothuroids were rare. Vermetid snails were abundant. The urchins, *Holocentrotus mammilatus* and *Echinostrephus aciculatus* were occasional.

As with other backreef sites, juvenile wrasses and the damselfish *Stegastes fasciolatus* dominated the abundance of fishes recorded. Small schools of large Kyphosids were seen both on and off the transect, but no other large fishes were seen that were not recorded within the transect boundaries.

### **MID-H11**

*N 28° 13.06', W 177° 24.193'*

Depth range: 3–4 m

Permanent transects. ARMS installed. This is a shallow patch reef site with much rubble and low coral cover (3.6%) with *Pocillopora damicornis* and *P. meandrina* being the two most common corals within the survey area. Dead *Pocillopora* colonies were scattered and several live colonies exhibited compromised health states with fleshy algae and cyanobacteria overgrowth.

This site had a high macroalgal percent cover and diversity with almost all macroalgae being highly epiphytized with turf algae and a cyanobacteria.

#### Species Found During LPI Survey

*Microdictyon setchellianum*  
*Styopodium flabelliforme*  
*Padina* sp.  
*Halimeda velasquezii*  
*Dictyota sandvicensis*  
*Turbinaria ornate*

*Codium arabicum*  
*Boodlea composita*  
*Liagora* sp.  
 Crustose coralline red algae  
*Laurencia galtsoffii*  
*Galaxaura* sp.

#### *Species Documented During Roving Diver Survey*

*Dictyosphaeria versluisii*  
*Chondrophycus parvipapillatus*  
*Codium edule*  
*Jania* sp.  
*Galaxaura filamentosa*  
*Halimeda discoidea*  
*Halymenia stipitata*

This patch reef site was dominated by the boring urchin, *Echinometra mathaei*, followed by *Holocentrotus mammilatus*. Trapezid crabs and *Calcinus* hermit crabs were common in *Pocillopora* heads. *Opiocoma pica* was common and Vermetid snails were abundant.

As with other lagoon patch reef sites at Midway, this site was dominated by juvenile wrasses and the damselfish, *Stegastes fasciolatus*. A few large schools of *Kyphosis* and *Mulloidichthys vanicolensis* were seen both on and off transect. A group of spinner dolphins visited the periphery of the site as divers were ascending.

#### **MID-165**

N 28° 15.578', W 177° 23.518'

Depth: 3 m

This site was located in the northern lagoon of Midway. It was established by the REA fish team as a new sampling location in the shallow lagoon stratum. This was a patch of reef surrounded by sand and composed of dead coral and rubble with moderate to high complexity and relief. It was shallow high energy area at 3 m depth. The dead coral was covered with turf algae and there were scattered *Pocillopora meandrina* heads at less than 4% coral cover. There were four large *Aprion virescens* at off transect. Juvenile wrasses and scarids were the most abundant fishes present.

#### **MID-156**

N 28° 16.632', W 177° 22.093'

Depth: 1 m

This site was located on the northern backreef of Midway Atoll. It was established by the REA fish team as a new sampling location in the shallow backreef stratum. *Montipora* spp., especially *M. flabellata*, were the dominant corals with 70 to 80% live coral cover, with *M. flabellata* at 60 % coral cover, and scattered *Pocillopora* heads. Complexity and relief in this area was moderate due to the large colonies of *M. flabellata* being close to the surface. Juvenile wrasses and scarids were the dominant families at this site.

#### **MID-112**

N 28° 11.49', W 177° 23.513'

Depth: 10 m

This site was located in the southern forereef of Midway Atoll. It was established by the REA fish team as a new sampling location in the moderate forereef stratum. This site had very low coral cover (~ 3%), consisting mainly of small patches of *Porites lobata*. Rugosity was high, with large boulders and rocky outcroppings napped in turf algae contorted into ledges and overhangs, providing shelter for soldierfish (*Myripristis berndti* and *M. amaena*). Fish diversity was relatively high. A large school of the goatfish *Mulloidichthys vnicolensis* swarmed through the transect and eventually merged with large schools of Acanthurids lurking off transect. Other species of note seen off transect were knifejaws, a large jobfish, and a very curious small Galapagos reef shark.

**MID-164**

N 28° 11.923', W 177° 20.753'

Depth: 11 m

This site was located on the southern forereef, approximately half a mile east of the boat channel opening. It was established by the REA fish team as a new sampling location in the moderate forereef stratum. Substrate was composed of small patch reefs surrounded by sand and algae dominated, primarily a *Dictyota* species. Tufts of algae were also floating in water column. Fish diversity was low, the most numerous species in the area being *Thalassoma duperrey* and *Coris venusta*. A pair of *Heniochus diphreutes* was a noteworthy species that was recorded on transect. Large *Naso unicornis* and several *Aprion virescens* were also observed off transect.

**MID-170**

N 28° 12.147', W 177° 22.012'

Depth: 2 m

This site was within the backreef on the south end of the atoll. It was established by the REA fish team as a new sampling location in the shallow backreef stratum. Substrate was patchreef surrounded by rubble. Fish diversity was low, but species present were numerous. The fish population was composed mainly of juvenile *Thalassoma duperrey*, *Coris venusta*, *Acanthurus triostegus*, and *Stegastes fasciolatus*. Though the site was located in shallow water, at least three different *Carcharhinus galapagensis* were identified, all of which appeared on site at different times after the previous shark had left. There were also a couple of large *Aprion virescens* off transect.

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**MID-02**

N 28° 11.843', W 177° 20.765'

Depth range: 11–13 m

Permanent transects. ARMS installed at this site. This site is located very near site MID-164 on the south forereef, approximately half a mile east of the boat channel opening. This site was characterized as sand flat with small patches of hard substrate with low coral cover (1.2%). The most common coral species found were *Pocillopora meandrina* and *Porites lobata*. Evidence of predation on multiple *P. meandrina* colonies and relatively low levels of coral bleaching were observed.

The benthos at this site was dominated by turf algae, a species of *Padina* and *Dictyota ceylanica*, with some tufts of algae floating in the water column. *Dictyosphaeria cavernosa* and *Lobophora variegata* were also documented during the LPI survey. *Distromium flabellatum*, *Halimeda velasquezii*, *Laurencia galtsoffii*, species of *Galaxaura*, *Neomeris* and *Jania*, and a cyanobacteria were documented during the Roving Diver survey.

No invert survey was conducted due to ARMS installment.

Fish diversity was low, the most numerous species in the area being *Thalassoma duperrey* and *Coris venusta*. Large *Naso unicornis* and several *Aprion virescens* were also observed off transect. A school of approximately 10–15 *Parupeneus pleurostigma* in the 15 cm range was observed feeding in the water column, 15–20 feet from the bottom.

### **MID-03**

N 28° 13.074', W 177° 20.644'

Depth range: 6–8 m

Permanent transects. Two large pinnacles separated by about 3 meters constitute the majority of substrate in the middle of vast sand flats at this site. Due to the lack of horizontal surfaces, transects are wrapped around the pinnacles. Coral cover is relatively low (9.3%) with *Porites compressa* being most common. On one of the pinnacles, large encrusting colonies of *Pavona variaians* were common but exhibited considerable partial mortality as well as pale pigmentation. Predation and low levels of coral bleaching were observed on *P. meandrina* and *P. compressa* colonies.

Turf algae dominated the benthos and a low percent cover of crustose coralline red algae and *Lobophora variegata* was documented during the LPI survey. The 20-ft depth was the main depth range of the transects and the base of the pinnacles; no other algal species were documented during the Roving Diver survey. However, at the 15-ft depth range, the tops of the pinnacles, the following algae were documented during the Roving Diver survey:

*Dictyosphaeria cavernosa*  
*Dictyosphaeria versluysii*  
*Microdictyon setchellianum*  
*Caulerpa serrulata*  
*Ventricaria ventricosa*  
*Halimeda velasquezii*  
*Jania sp.*

The dominant macroinvertebrates were the sea cucumbers, *Actinopyga obesa* and *Bohadschia paradoxa*. The sea cucumber, *Holothuria atra*, was prevalent off transect in the sand. Several *Ophiocoma erinaceus* were seen within and underneath the rubble. Vermetid snails were abundant. An unidentified sponge, c.f. *Plakortis*, was prevalent.

It was not possible for two fish divers to work on the transect here, as there was too much overlap between divers. To avoid confusion, the divers split up and each surveyed a bommie alone. Each bommie supported a wide variety of species. *Dascyllus albisella* was the most abundant species on transect A. Just off of the bommies over the sand there were 70 to 80 *Mulloidichthys flavolineatus* at 30 to 35 cm, 150 *Kyphosid* sp. at 20 to 30 cm, 30 *Decapterus macarellus* at 15 cm, and 1 *Aprion virescens* at 65 cm.

## **MID-R20**

N 28° 13.89', W 177° 19.091'

Depth range: 1 m

Permanent transects. The backreef habitat at this site is dominated by algae with only 4% coral cover. The most abundant coral species were *Porites lobata* and *Pocillopora meandrina*. Compromised coral health states were observed in several species including bleaching, predation and algal interactions.

The benthos at this site was dominated by turf algae, *Styopodium flabelliforme*, and *Laurencia galtsoffii*. *Lobophora variegata* and crustose coralline red algae were also documented during the LPI survey. *Boodlea composita* was documented at this site in low percent cover (N 28° 13.904' W 177° 19.100'). Other species documented during the Roving Diver survey include *Portieria hornemannii*, *Dictyota ceylanica*, *Boodlea composita*, and a species of *Sargassum*.

The dominant macroinvertebrate was the boring urchin, *Echinometra mathaei*, followed by *Holocentrotus mammilatus*. The sea cucumber, *Actinopyga obsesa*, was prevalent off-transit. Vermetid snails were abundant.

This shallow backreef site supported a large school of *Naso unicornus*. Herbivorous acanthurids and wrasses were prevalent at this site. Transect A held the highest number of fish and the highest species diversity. Transect B was closest to the reef crest in a high energy shallow area with a strong current and was depauperate of fish, except for a large number of juvenile *Coris venusta* and *Thalassoma duperrey*.

### F.3. Benthic Environment

#### F.3.1. Algae

Benthic communities around Midway Atoll were dominated by turf and macroalgal functional groups (Table F.3.1.1.). A combined total of 23 species of macroalgae were observed (7 chlorophytes, 5 ochrophytes, 11 rhodophytes) from the 9 sites surveyed (Tables F.3.1.2., F.3.1.3.). Individuals of *Laurencia galtsoffii* were the most prevalent species encountered at three of the nine sites surveyed and covered 0% to 35.2% of the substrate across all sites (Table F.3.1.2.). Individuals of *Microdictyon setchellianum* were the most prevalent species documented at sites MID-02 and MID-H11, where they covered 25.2% and 31.6%, respectively (Table F.3.1.2.). *Dictyota ceylanica*, *Lobophora variegata*, *Styopodium flabelliforme* and a species of *Padina* dominated the substrate at one of the nine sites surveyed (Table F.3.1.2.). Overall, turf algae dominated the algal community at six of the nine sites surveyed with a percent cover range of 15.6% to 84.8% (Table F.3.1.1.). Macroalgae dominated the algal community at three of the nine sites, 0.8% to 49.2% percent cover across all sites (Table F.3.1.1.).



Table F.3.1.1.--Percent cover of algal functional groups at long-term monitoring sites at Midway Atoll.

Site	Macroalgae	Turf algae	Coralline red algae (crustose + upright)	Cyanobacteria
MID-01	9.2%	37.2%	2.8%	0.8%
MID-02	44.8%	15.6%	-	-
MID-03	0.8%	84.8%	1.6%	-
MID-R3	12.4%	75.2%	2.8%	3.6%
MID-R7	39.2%	50.8%	0.4%	-
MID-H10	36.8%	52.8%	1.6%	2.0%
MID-H11	49.2%	18.0%	3.6%	25.2%
MID-R20	48.8%	34.4%	6.4%	0.4%
MID-H21	6.8%	40.0%	2.4%	0.8%

Table F.3.1.2--Additional species recorded at each site at Midway Atoll during Roving Diver survey.

Site	<b>Chlorophyta</b>
MID-R20	<i>Boodlea composita</i>
MID-H11	<i>Codium edule</i>
MID-R7 MID-H10 MID-H11 MID-H21	<i>Dictyosphaeria versluysii</i>
MID-H11	<i>Halimeda discoidea</i>
MID-01 MID-02 MID-R3 MID-H21	<i>Halimeda velasquezii</i>
MID-H21	<i>Microdictyon setchellianum</i>
MID-01 MID-02 MID-H21	<i>Neomeris</i> sp.
	<b>Ochrophyta</b>
MID-R20	<i>Dictyota ceylanica</i>
MID-02	<i>Distromium flabellatum</i>
MID-R20	<i>Sargassum</i> sp.
MID-H21	<i>Stypopodium flabelliforme</i>
MID-H21	<i>Turbinaria ornate</i>
	<b>Rhodophyta</b>
MID-H11	<i>Chondrophycus parvipapillatus</i>
MID-H10 MID-H11	<i>Galaxaura filamentosa</i>
MID-02	<i>Galaxaura</i> sp.
MID-01	<i>Halichrysis coalescens</i>
MID-H11	<i>Halymenia</i> sp.
MID-02 MID-H10 MID-H11	<i>Jania</i> sp.
MID-02	<i>Laurencia galtsoffii</i>
MID-H11	<i>Liagora</i> sp.
MID-H10	<i>Martensia</i> sp.
MID-01	<i>Peyssonnelia</i> sp.
MID-R20	<i>Portieria hornemannii</i>

Table F.3.1.3.--Percent cover of macroalgal species at long-term monitoring sites at Midway Atoll. Sum totals for each row equal the percent cover of macroalgae recorded in Table F.3.1.1.

Site	<i>Boodlea composita</i>	<i>Codium arabicum</i>	<i>Dictyosphaeria cavernosa</i>	<i>Dictyosphaeria versluysii</i>	<i>Halimeda discoidea</i>	<i>Halimeda velasquezii</i>	<i>Microdictyon setchellianum</i>	<i>Dictyota ceylanica</i>	<i>Dictyota sandwichensis</i>	<i>Lobophora variegata</i>	<i>Padina</i> sp.	<i>Sargassum</i> sp.	<i>Stypopodium flabelliforme</i>	<i>Turbinaria ornata</i>	<i>Dasya iridescens</i>	<i>Galaxaura</i> sp.	<i>Laurencia galtsoffii</i>
MID-01	-	-	-	0.4%	-	-	-	-	-	3.6%	-	0.4%	-	0.4%	-	-	4.4%
MID-02	-	-	0.4%	-	-	-	25.2%	7.6%	-	0.4%	10.8%	-	-	-	0.4%	-	-
MID-03	-	-	-	-	-	-	-	-	-	0.8%	-	-	-	-	-	-	-
MID-R3	-	-	-	-	-	-	-	1.2%	-	10.8%	0.4%	-	-	-	-	-	-
MID-R7	-	-	-	-	-	-	-	34.4%	-	4.0%	0.8%	-	-	-	-	-	-
MID-H10	-	-	-	-	-	-	-	0.4%	-	8.0%	0.8%	-	-	-	-	-	27.6%
MID-H11	0.4%	0.8%	-	-	-	0.8%	31.6%	-	1.6%	2.0%	5.2%	-	4.8%	0.4%	-	0.4%	1.2%
MID-R20	-	-	-	0.4%	1.2%	0.4%	2.4%	-	-	2.4%	-	-	6.8%	-	-	-	35.2%
MID-H21	-	-	-	-	-	-	-	-	-	3.6%	-	2.8%	-	-	-	0.4%	-

### F.3.2. Corals

#### F.3.2.1 Coral Populations

LPI surveys indicate that coral cover at REA sites around Midway in 2008 varied with both habitat and region. Mean coral cover was low inside the lagoon ( $6.6 \pm 3.0\%$ ) and on the forereef ( $4.0 \pm 1.5\%$ ), while mean cover was moderately high in the backreef ( $32.3 \pm 14.2\%$ ).

Coral community structure varied both between and within habitats. The two northern backreef sites consisted of large encrusting colonies of *Montipora flabellata* and *M. Capitata*, and *M. turgescens*. The eastern backreef site was characterized by scattered *Porites lobata* and *Pocillopora* heads. On the forereef, the western site was scoured and corals were quite depauperate, most likely due to strong wave action. The two southern forereef sites behind Sand Island were composed largely of *Porites* sp., while the forereef site south of Eastern Island was composed of mostly *Pocillopora* sp. The coral communities at the two lagoonal patch reef sites were quite different with one being dominated by old *Porites compressa* mounds (MID-03) and the other (MID-H11) being dominated by scarce *Pocillopora* heads.

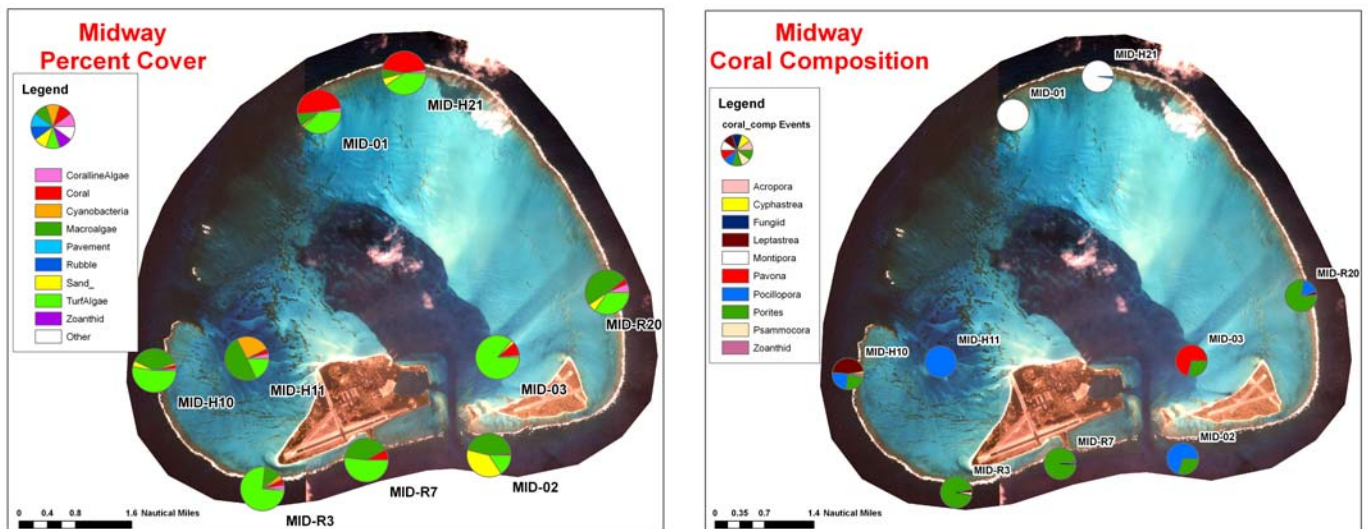


Figure F.3.2.1.1.--Spatial distribution of benthic cover and coral composition for REA sites at Midway in 2008.

Table F.3.2.1.1.--Relative percentage of coral taxon enumerated within belt transects for three habitat strata at Midway in 2008.

Backreef		Forereef		Lagoon	
Taxon	Percent	Taxon	Percent	Taxon	Percent
Montipora flabellata	58.0	Porites lobata	59.5	Porites compressa	34.6
Cyphastrea ocellina	7.5	Pocillopora meandrina	11.1	Pocillopora damicornis	31.7
Pocillopora damicornis	6.8	Porites evermanni	10.7	Pocillopora meandrina	12.7
Montipora turgescens	6.5	Leptastrea purpurea	5.1	Pavona varians	12.7
Pocillopora meandrina	6.1	Palythoa sp.	4.9	Porites evermanni	3.4
Porites lobata	5.1	Psammocora stellata	2.3	Porites lobata	2.0
Montipora capitata	4.2	Cyphastrea ocellina	2.1	Psammocora stellata	1.5
Porites sp	4.0	Pocillopora sp	1.9	Leptastrea purpurea	0.5
Fungia scutaria	0.7	Porites compressa	1.2	Cyphastrea ocellina	0.5
Pocillopora sp	0.7	Montipora flabellata	0.2	Pocillopora sp	0.5
Leptastrea purpurea	0.5	Pocillopora damicornis	0.2		
		Montipora turgescens	0.2		

#### F.3.2.2. Coral Disease

An extremely low level of thermal stress was posted by NOAA's Coral Reef Watch on September 4, noting that sea surface temperature at Midway was 0.1 degrees higher than the maximum monthly mean sea surface temperature for September. This temperature difference is very small and we are happy to say that very low levels of bleaching were observed around Midway. Few colonies showed signs of bleaching on the forereef and inside the lagoon with the exception of colonies of *Cyphastrea ocellina*, many of which appeared pale compared to colonies which were shaded and had full pigmentation (however, this pale pigmentation may be within the natural of color variability of the coral). In the backreef, about 15% of *Montipora capitata* colonies appeared to be bleached and many were suffering from partial mortality with algae overgrowth.

Overall, the coral communities around Midway seemed healthy, with the forereef showing the lowest levels of bleaching, coral disease and partial mortality. Algal interactions affected several species in the backreef while in the lagoon, colonies of *Pavona varians* exhibited relatively high percentages of partial mortality, with some colonies appearing pale and being affected by cyanobacteria.

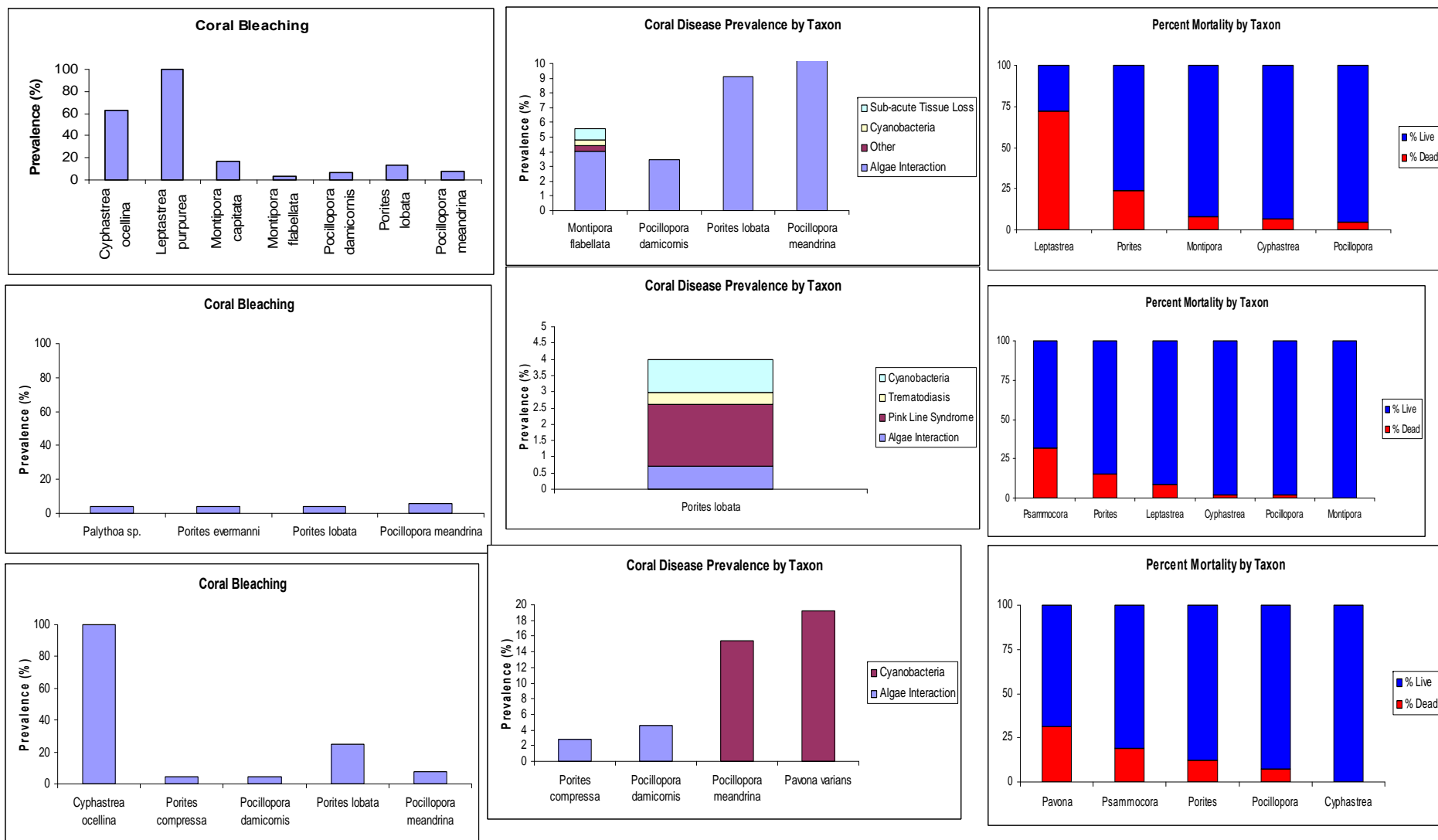


Figure F.3.3.2.1.--Left: Prevalence of bleached colonies for seven taxon at Midway. Middle: Prevalence of coral disease by disease state for eight coral taxon. Right: Relative percent of dead surface area for ten coral genera at Midway. For each group of graphs, the top graph is for the backreef, middle is forereef, and bottom is lagoon.

### F.3.3. Non-coral Invertebrate Surveys

A total of 8370 individuals of benthic invertebrate target species or taxa group were enumerated from 16 belt transects at 8 sites. The sea urchin, *Echinostrephus aciculatus*, was the most abundant benthic invertebrate in forereef sites ( $n = 3$ ), and *Echinometra mathaei* was the most abundant benthic invertebrate in backreef ( $n = 3$ ) and lagoon ( $n = 2$ ) sites (mean density 16.42, 4.96, and 6.98/m<sup>2</sup>, respectively). The forereef site, MID-R3, had the highest density of *Echinostrephus aciculatus* with 28/m<sup>2</sup> and the lagoon site, MID-H11, had the highest density of *Echinometra mathaei* with 13.94/m<sup>2</sup>. The urchin, *Heterocentrotus mammilatus* and trapezid crabs were common at MID-H11 (0.27 and 0.13/m<sup>2</sup>, respectively). The holothuroids, *Actinopyga obesa* and *Bohadaschia paradoxa*, were abundant at site MID-03 (0.1 and 0.14/m<sup>2</sup>, respectively). *Holothuria atra* and *H. whitmaei* were also prevalent at site MID-03 but off transect. Vermetid snails were abundant at MID-03 and MID-R20 and the sea slug, *Plakobranthus ocellatus*, the brittle stars, *Ophiocoma pica* and *O. erinaceus*, and an unidentified black sponge, c.f. *Plakortis*, were abundant at MID-03.

#### F.3.3.1.--Urchin Measurements

Figure F.3.3.1.1. reveals the average test diameter of urchins encountered at each site. Only sites where  $\geq 5$  measurements were recorded for a species are represented.

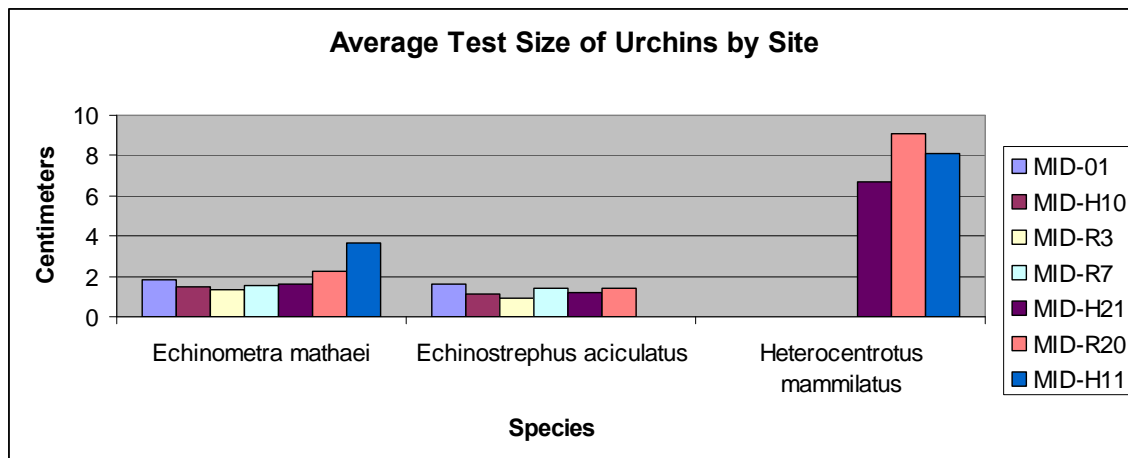


Figure F.3.3.1.1.--Average test size of urchins by site.

Figure F.3.3.1.2. reveals the average test diameter of urchins by stratum. Only stratum where  $\geq 5$  measurements were recorded for a species are represented.

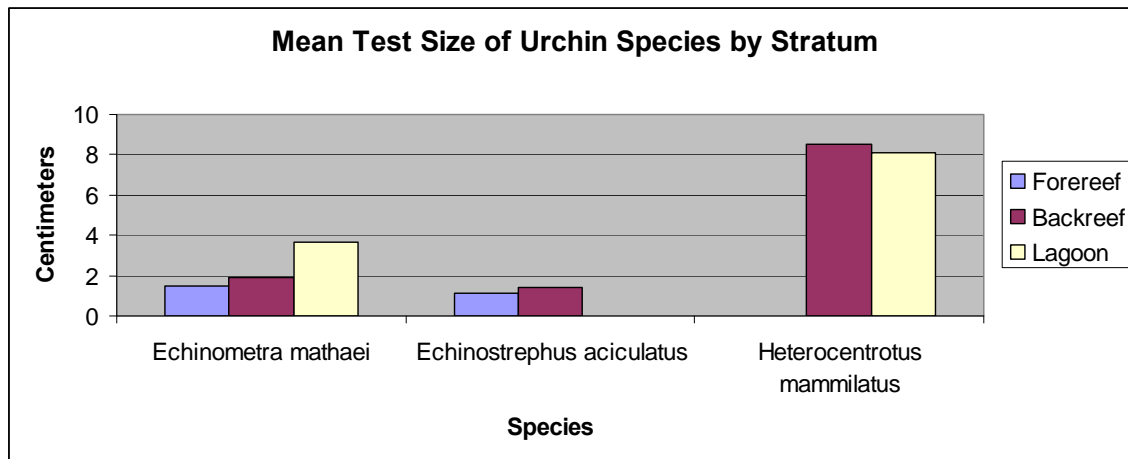


Figure 3.3.1.2.--Mean test size of urchin species by stratum.

#### F.3.3.2. ARMS Deployment

ARMS were deployed at the following REA sites around Midway. Each site contains three ARMS.

Table F.3.3.2.1.--ARMS deployment locations around Midway Atoll.

	Latitude	Longitude
MID-R3	28° 11.420 N	-177° 23.972 W
MID-R7	28° 11.782 N	-177° 22.501 W
MID-H11	28° 13.060 N	-177° 24.193 W
MID-02	28° 11.843 N	-177° 20.765 W

#### F.3.4 Towed-diver Benthic Surveys

The 16 towed-diver benthic habitat surveys of Midway Atoll were conducted along the outlying forereef habitat, along with sections of the backreef located along the northern and eastern expanses and a single lagoonal tow located near the northwestern channel entrance. The overall averages for substrate composition and macroinvertebrate population densities are illustrated in the tables below (Tables F.3.4.1., F.3.4.2.).



Table F.3.4.1.--Overall benthic habitat composition.

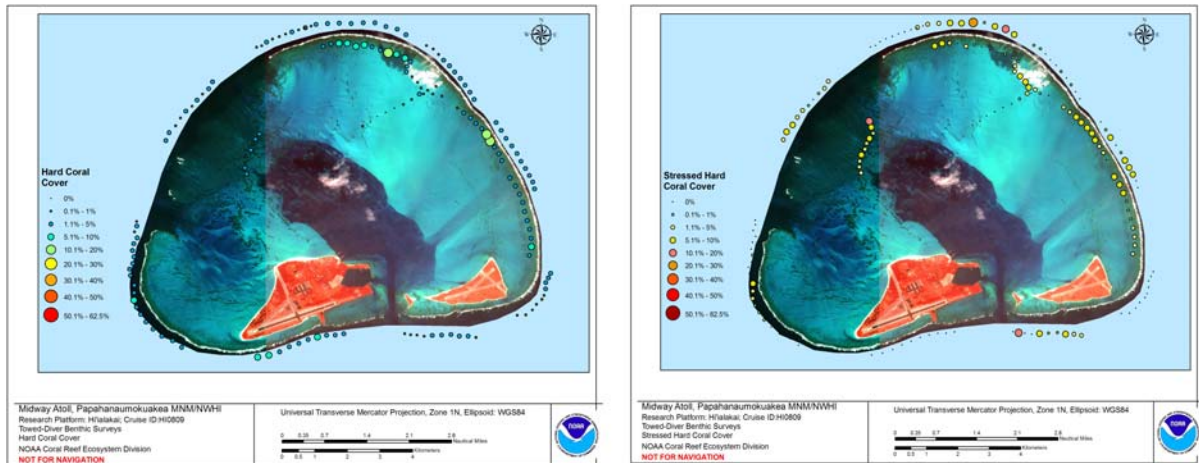
Substrate	Percent Cover (%)	Percent Cover Range (%)
Hard Coral	2.45	0–20
Stressed Hard Coral	2.37	0–30
Soft Coral	0.06	0–1
Sand	22.69	0.1–100
Rubble	13.93	0.1–75
Macroalgae	21.10	0.1–100
Coralline algae	5.09	0–40

Table F.3.4.2.--Overall macroinvertebrate population densities.

Macroinvertebrate	Density (#/hectare)	Total # Observed
<i>Acanthaster Planci</i> (COTs)	0.33	13
Boring sea urchins	1,889	73,663
Free-living sea urchins	9.47	169
Sea Cucumbers	25.64	1000

The forereef habitat around Midway Atoll was somewhat delineated by region; however, general forereef benthos composition consisted of primarily spur and groove/pavement and pavement reef interspersed with sand flats on all sides of the island. Backreef habitat consisted of a mix between sand and rubble flats, stretches of pavement and pavement reef, and continuous reef. The lagoonal survey primarily consisted of patch reef, pavement, rubble flats, and sand flats.

Hard coral cover was generally low island-wide, averaging around 2.45% and never exceeding 20%. The highest coral cover was generally located along several sections of the northern and eastern backreef, where coral composition was primarily composed of *Montipora capitata*, *Montipora flabellata*, *Pocillopora* sp., and *Porites* sp. Coral stress was generally low around the island, averaging 2.37% overall. However, several areas showed signs of low-moderate coral stress seen as pale/bleached colonies of *Pocillopora* and *Montipora*. While crown-of-thorns predation was recorded in a number of places, overall crown-of-thorn numbers were generally low and were not thought to be a major contributing factor to coral stress. The highest coral stress (10.1–20%) was recorded along the patch reefs and rubble flats in the east, which appeared to correspond with the localized bloom of *boodlea* in the region.

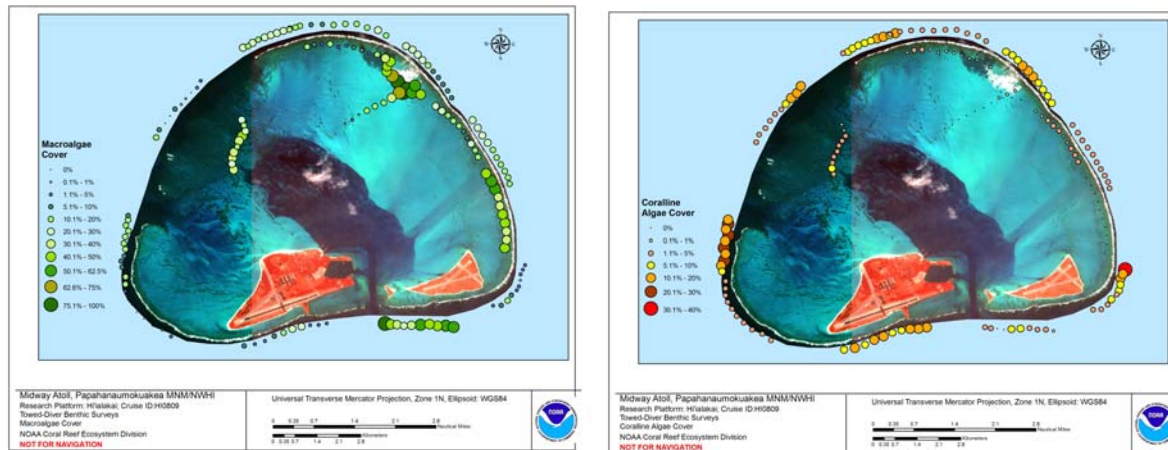


Figures F.3.4.1. and F.3.4.2.--Hard coral and stressed coral cover.

Macroalgae cover averaged 21.1% island-wide, and was generally highest along the eastern backreef areas (average 35.45%). Two towed-diver surveys approximately 8 kilometers to the north of East Island encountered a *boodlea* algae bloom, with several segments recording 100% cover of the benthos in a layer up to 0.5 meters thick. Coralline algae was generally low island-wide, recording 5.09% cover (range 0–40%). The highest coralline algae cover was generally noted along the northern forereef, reaching up to 50.1–62.5% cover.



Figure F.3.4.3.--*Boodlea* bloom noted along the eastern backreefs of Midway Atoll.



Figures F.3.4.4. and F.3.4.5.--Macroalgae and coralline algae cover.

Macroinvertebrate counts were generally low for crown-of-thorns, with only 13 individuals recorded during all combined surveys around Midway Atoll. Boring sea urchins recorded  $1,889/\text{ha}^{-1}$  and were highest along the southern shore, with many 5-minute time segments ( $\sim 200$  meters length) recording  $> 1001$  individuals. Free urchins were relatively uncommon, with all records noted within the lagoon and backreef environs. Finally, sea cucumber populations were highest during surveys conducted along the northern ( $0.43/\text{ha}^{-1}$ ) and southeastern ( $0.43/\text{ha}^{-1}$ ) backreefs of Midway Atoll.

## F.4 Fish

### F.4.1 REA Fish Surveys

#### *Belt transect data*

During the survey period, 41 belt transect surveys were conducted at 16 sites around Midway Atoll. Surgeonfish (Acanthuridae) was the largest contributor to total biomass with  $13.86 \text{ kg } 100 \text{ m}^{-2}$ . Chubs (Kyphosidae) were the second largest contributor to total biomass with  $11.72 \text{ kg } 100 \text{ m}^{-2}$ , followed by Parrotfish (Scaridae) at  $9.46 \text{ kg } 100 \text{ m}^{-2}$ . (Fig. F.4.1.1.).

#### *Overall observations*

A total of 111 fish species were observed during the survey period by all divers. The average total fish biomass at the sites at Midway during the survey period was  $17.53 \text{ kg } 100 \text{ m}^{-2}$  for the belt transect surveys (Table F.4.1.1.).

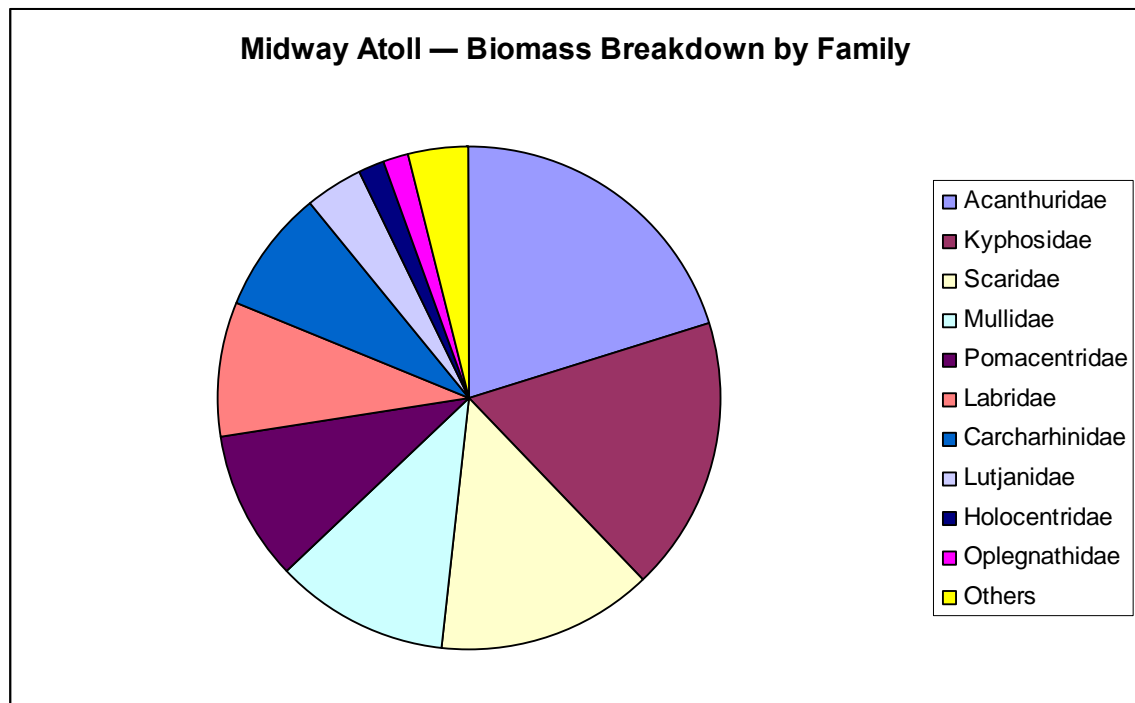


Figure F.4.1.1.--Total fish biomass composition by family.

**Table F.4.1.1.** --Coral reef fish biomass (kg 100 m<sup>-2</sup>) by family at sites around Midway Atoll.

Stratum – Depth	Site	Total	Acanth.	Carchar.	Holocen.	Kyphosid	Labrid	Lutjanid	Mullid	Opleg.	Pomacen.	Scarid	Others
Backreef – Shallow	MID-01	7.56	0.87	11.48	0.25	0.26	0.79		1.51		0.63	2.68	0.56
	MID-156	2.54	0.26		0.09	0.08	1.21		0.10		0.37	0.40	0.02
	MID-170	13.70	0.68				1.23		0.14		0.14		0.04
	MID-H21	4.86	0.10		0.01	0.05	1.05		1.60		0.56	1.37	0.10
	MID-R20	16.35	11.97		0.22		2.31		0.19		0.23	1.21	0.23
Forereef – Mid	MID-02	4.64	0.43			9.82	0.51	1.62	0.44	3.51	0.19	1.08	0.36
	MID-107	21.60	0.94				1.11		0.37		2.50	3.17	0.17
	MID-109	6.04	3.01				1.44	0.24	0.29		0.11	0.65	0.30
	MID-112	20.29	4.38			2.14	1.21		2.16		3.20	3.61	1.99
	MID-164	8.03	3.60				0.66	1.48	0.19	0.49	0.23	0.84	1.03
	MID-H10	14.88	3.83				0.64	0.39	0.05		2.56	2.41	2.90
	MID-R3	34.66	4.18			7.83	1.72	0.66	0.29		8.19	1.17	2.12
	MID-R7	36.11	3.04			17.57	4.14	2.11	0.18		2.30	2.48	2.18
Lagoon – Mid	MID-03	17.03	0.45		0.30	5.23	0.80		5.36		1.94	2.31	0.66
Lagoon – Shallow	MID-165	37.33	14.45		0.63	4.29	3.21	3.48	0.68	1.28	2.10	6.73	0.49
	MID-H11	9.86	0.98			2.27	2.09		1.42		1.45	1.45	0.20
<b>Average</b>		<b>17.53</b>	<b>3.72</b>	<b>12.29</b>	<b>0.66</b>	<b>4.10</b>	<b>1.43</b>	<b>1.32</b>	<b>0.95</b>	<b>1.76</b>	<b>1.84</b>	<b>2.19</b>	<b>0.91</b>

#### F.4.2 Towed-diver Fish Surveys

During the 2008 Reef Assessment Monitoring Program mission, the Coral Reef Ecosystem Division's (CRED) towboard team completed 16 surveys at Midway Atoll covering 39 km (39 ha) of ocean floor (Table F.4.2.1.). Mean survey length was 2.4 km with a maximum length of 3.2 km and a minimum of 1.9 km. Mean survey depth was 9 m with a maximum depth of 16.9 m and a minimum of 0.7 m in the backreef. Mean temperature on these surveys was 27.2 °C with a maximum temperature of 28.0 °C and a minimum of 26.9 °C.

Table F.4.2.1.--Survey statistics for towboard sampling during HI-08-09.

Island/Atoll/Reef	#	Length (km)					Depth (m)				Temperature (°C)			
		Sum	Mean	Max	Min	SD	Mean	Max	Min	SD	Mean	Max	Min	SD
Kure	14	32	2.3	2.7	1.8	0.02	8.2	16.5	0.9	5.9	26.8	27.3	25.5	0.4
Midway	16	39	2.4	3.2	1.9	0.03	9	16.9	0.7	5.9	27.2	28	26.9	0.3
Pearl & Hermes	27	63	2.3	3.1	1.3	0.03	10.3	16.3	1.2	5.2	27.3	27.9	26.8	0.3
Lisianski	12	24.7	2.1	2.3	1.7	0.02	10	14.2	1.6	3.9	28	28.2	27.8	0.1
Laysan	5	11.5	2.3	2.5	2.1	0.01	11.8	13.6	9.2	1.5	27.9	28	27.8	0.1
Maro Reef	11	23.4	2.1	2.4	1.7	0.01	13.3	16.5	9.5	1.8	28.2	28.4	27.9	0.1
French Frigate	26	56.5	2.2	2.9	1.4	0.03	11.5	17.1	1.8	4.5	27.6	28.3	26.9	0.2

Twenty-three species of large-bodied reef fish (> 50 cm TL) were encountered at Midway Atoll (Table F.4.2.2.). Overall numeric density for this class of reef fishes was 0.105 #/100m<sup>2</sup> (10.456 t/ha) with a biomass density of 0.347 kg/100m<sup>2</sup> (0.035 t/ha). Numeric and biomass density was dominated by *Chlorurus perspicillatus*. Overall, scarids contributed 44% of the overall numeric density (Fig. F.4.2.1.) 33% of the overall biomass (Fig. F.4.2.2.).

Biomass density was higher in the forereef environment compared to the backreef and was slightly higher in the south and southeast quadrants of the atoll (Fig. F.4.2.3.). *Chlorurus perspicillatus* was found around the entire periphery of the atoll. High biomass levels of *Pseudocaranx dentex* were found near the southeastern tip of Eastern Island. High levels of *Naso brevirostris* and *Naso hexacanthus* were found along the southern coast of Sand island possibly indicating an area of upwelling. *Aprion virescens* was found in all areas except for the break in the reef line on the western side of the atoll.

Table 4.2.2.--Species numeric and biomass density for large-bodied reef fish (>50 cm TL) observed at Midway Atoll during 2008 CRED towed-diver surveys.

Species	#	#/100m <sup>2</sup>	#/ha	Biomass		
				(kg)	kg/100m <sup>2</sup>	t/ha
Aetobatus_narinari	1	0.000	0.026	14.468	0.004	0.000
Aluterus_scriptus	2	0.001	0.051	0.550	0.000	0.000
Aprion_virescens	51	0.013	1.307	298.726	0.077	0.008
Aulostomus_chinensis	2	0.001	0.051	0.837	0.000	0.000
Carangoides_orthogrammus	5	0.001	0.128	11.491	0.003	0.000
Caranx_melampygus	11	0.003	0.282	24.835	0.006	0.001
Carcharhinus_amblyrhynchos	1	0.000	0.026	6.509	0.002	0.000
Carcharhinus_galapagensis	5	0.001	0.128	119.340	0.031	0.003
Chlorurus_perspicillatus	178	0.046	4.562	453.900	0.116	0.012
Coris_flavovittata	2	0.001	0.051	8.800	0.002	0.000
Diodon_hystrix	1	0.000	0.026	3.062	0.001	0.000
Epinephelus_quernus	2	0.001	0.051	18.534	0.005	0.000
Gymnothorax_meleagris	1	0.000	0.026	0.263	0.000	0.000
Kyphosus_sp	8	0.002	0.205	23.161	0.006	0.001
Myrichthys_magnificus	1	0.000	0.026	0.432	0.000	0.000
Naso_brevirostris	10	0.003	0.256	34.440	0.009	0.001
Naso_hexacanthus	4	0.001	0.103	8.485	0.002	0.000
Naso_unicornis	56	0.014	1.435	143.779	0.037	0.004
Oplegnathus_fasciatus	6	0.002	0.154	19.950	0.005	0.001
Oplegnathus_punctatus	28	0.007	0.718	71.890	0.018	0.002
Parupeneus_cyclostomus	3	0.001	0.077	4.650	0.001	0.000
Parupeneus_porphyreus	2	0.001	0.051	3.825	0.001	0.000
Pseudocaranx_dentex	28	0.007	0.718	80.239	0.021	0.002
Grand Total	408	0.105	10.456	1352.166	0.347	0.035
# of Species	23					

Numeric Density Contribution by Family for Large-Bodied Reef Fish (>50cmTL)  
observed at Midway Island During 2008 CRED Towed-Diver Surveys

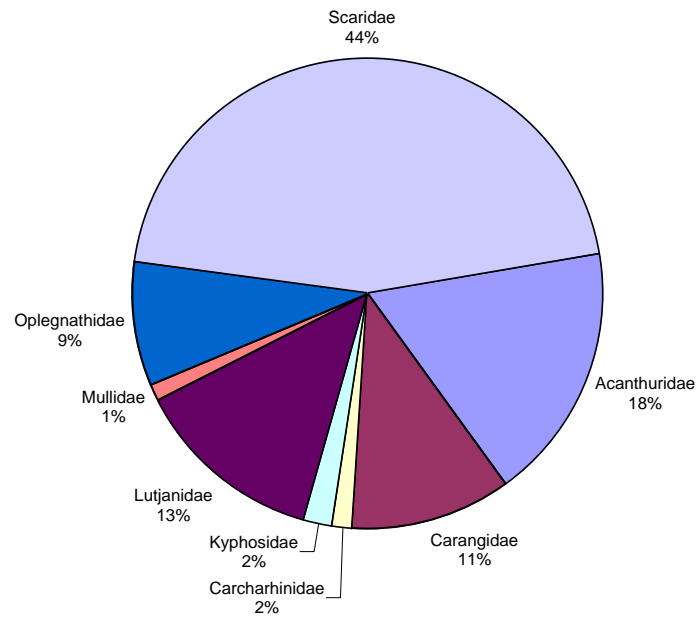


Figure F.4.2.1.--Numeric density by family.

Biomass Density Contribution by Family for Large-Bodied Reef Fish (>50cmTL)  
observed at Midway Island During 2008 CRED Towed-Diver Surveys

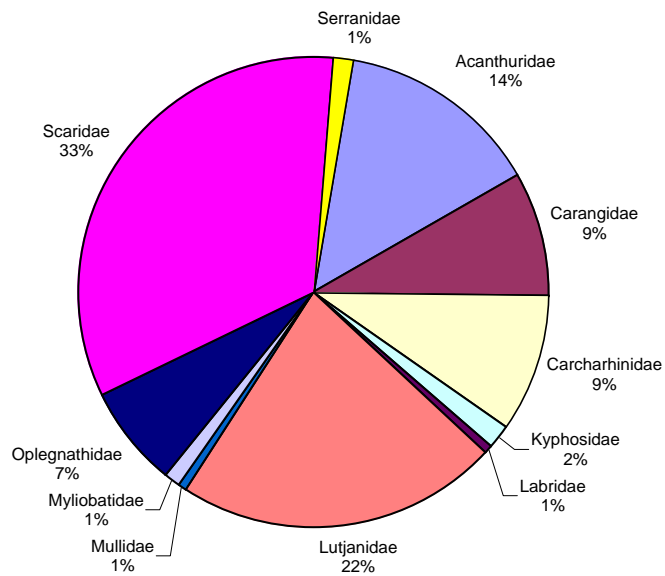


Figure F.4.2.2.--Biomass density by family.



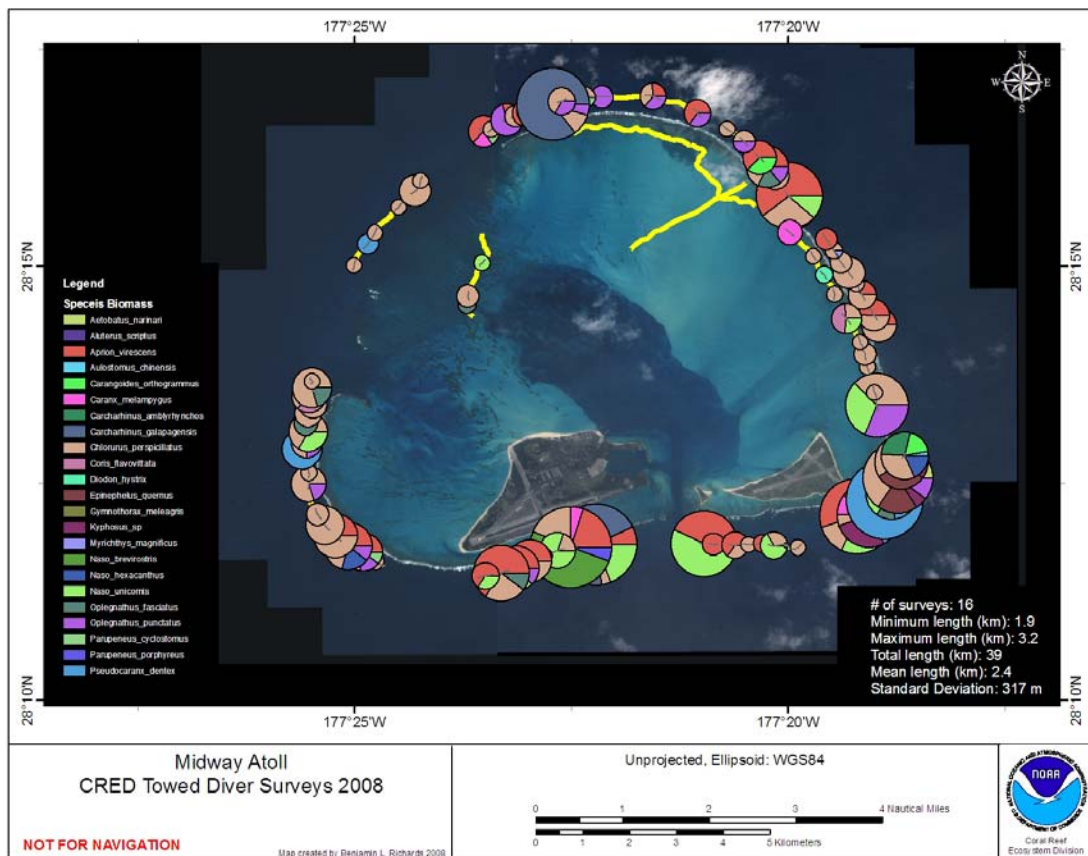


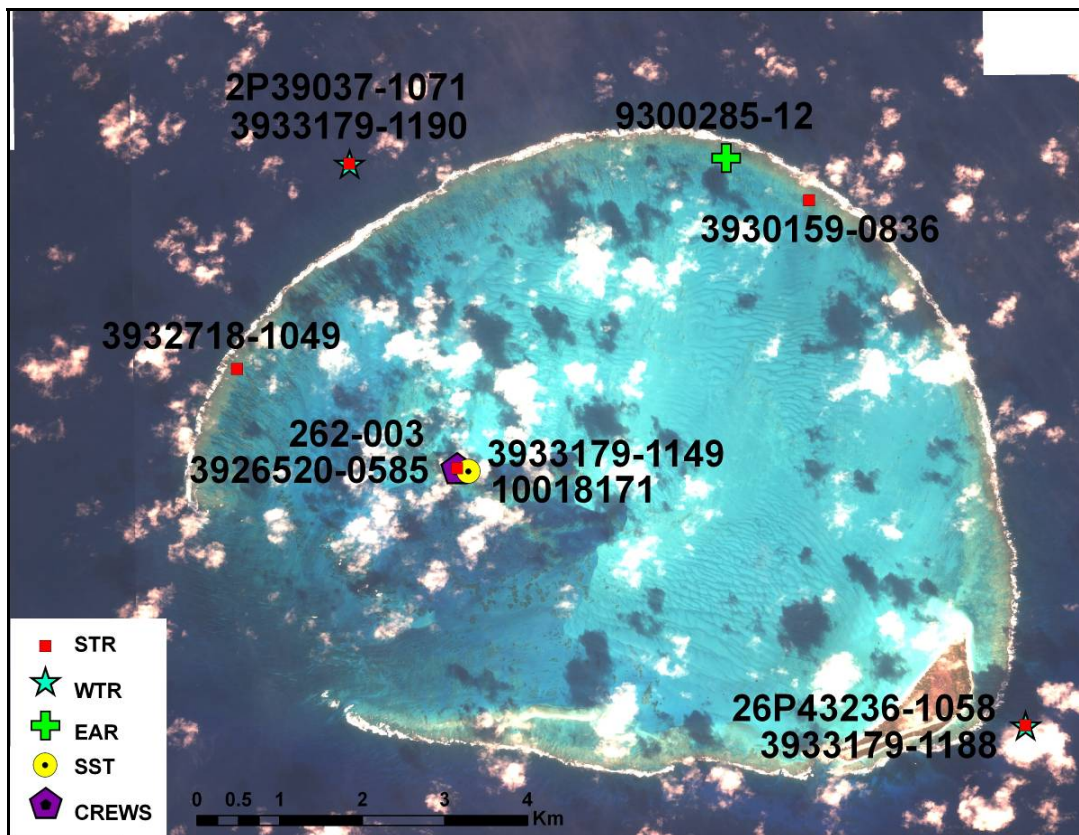
Figure F.4.2.3.--Geographic distribution of biomass around Midway Atoll. Each species is represented by a legend color. Diameter of pie chart is proportional to total biomass of all species encountered on the underlying survey.

## Appendix G: Kure Atoll

### G.1. Oceanography and Water Quality

#### Moorings (Fig. G.1.1., Table G.1.1.)

At Kure Atoll during HI0809, one sea surface temperature (SST) buoy was installed in place of one that was lost, reusing the original anchor, and a Coral Reef Early Warning System buoy (CREWS, which includes a Seabird 37 salinity and temperature recorder, a UV sensor, an anemometer and a Seabird 39 temperature recorder) was removed. Two Wave and Tide Recorders (WTRs) were removed and replaced, one from the southeast corner and one from the northwest side of the atoll. New mooring deployments at Kure included a new ecological acoustic recorder (EAR) site. This EAR mooring was removed from the northern backreef and relocated on the southern forereef in approximately 12 m of water. Six subsurface temperature recorders (STRs) were removed and six were deployed, four of these were replaced in the same position, two were removed with the CREWS buoy and anchor, and one was deployed with the EAR. Due to instrumentation problems, the two Seabird 26+ WTRs from Kure were removed, downloaded, cleaned, and the same instruments were returned to their moorings. This was done due to the extended battery life of the 26+ over the older version 26 WTR.



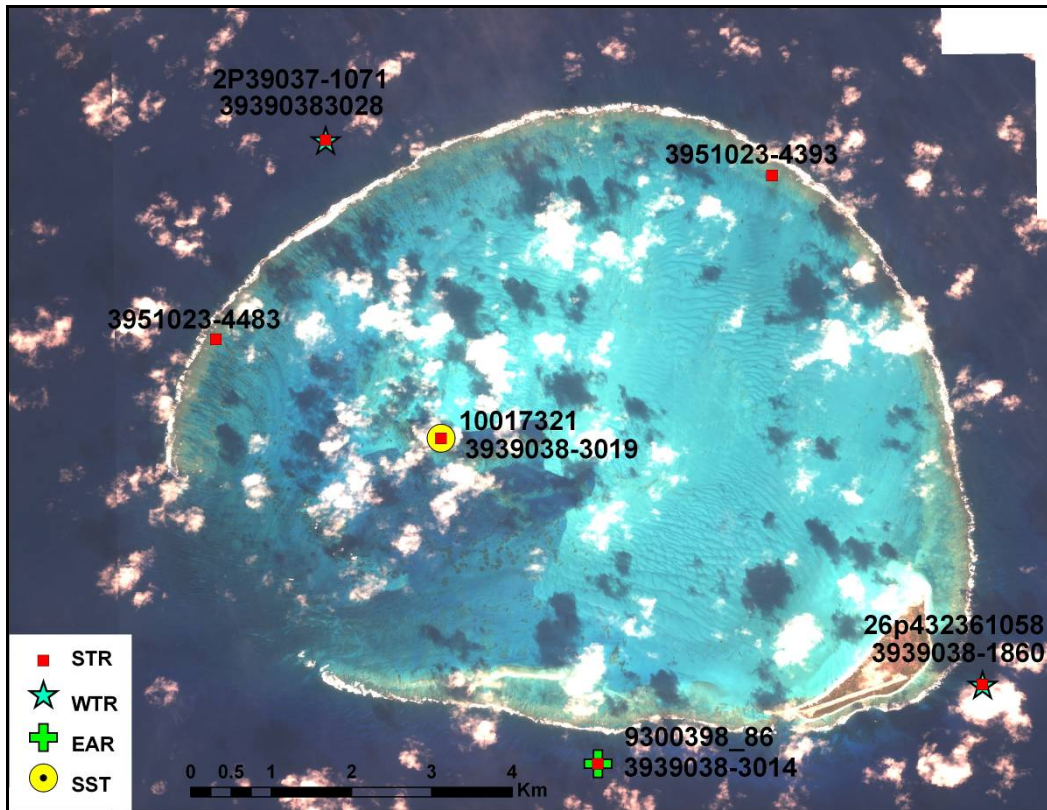


Figure G.1.1.--Moored oceanographic instrumentation map for Kure Atoll. Instruments recovered (top) and instruments deployed (bottom).

Table G.1.1.--Moored oceanographic instrumentation table for Kure Atoll.

Instrument	Action	Serial Number	Latitude	Longitude	Data Start	Data End	Depth (m)
SST	Deployment	10017321	28.41817	-178.34327	29-Sep-08	Logging	0.00
STR	Deployment	3939038-3019	28.41817	-178.34327	29-Sep-08	Logging	10.06
STR	Retrieval	3933179-1149	28.41852	-178.34453	17-Sep-06	30-Sep-08	10.36
SST	Other	10018171	28.41817	-178.34327	16-Sep-06	Lost at sea	0.00
CREWS	Retrieval	262-003	28.41852	-178.34453	16-Sep-06	29-Sep-08	0.91
STR	Retrieval	3926520-0585	28.41852	-178.34453	16-Sep-06	29-Sep-08	0.91
EAR	Retrieval	9300285-12	28.45212	-178.31524	--	--	2.13
EAR	Deployment	9300398_86	28.38171	-178.32571	29-Sep-08	Logging	12.5
STR	Deployment	3951023-4393	28.44759	-178.30621	29-Sep-08	Logging	0.91
STR	Retrieval	3930159-0836	28.44759	-178.30621	16-Sep-06	29-Sep-06	0.91
STR	Deployment	3951023-4483	28.42927	-178.36847	29-Sep-08	Logging	0.91
STR	Retrieval	3932718-1049	28.42927	-178.36847	16-Sep-06	29-Sep-06	0.91
WTR	Retrieval	26p432361058	28.39061	-178.28265	16-Sep-06	15-May-08	19.20
WTR	Deployment	26p432361058	28.39061	-178.28265	29-Sep-08	Logging	19.20
STR	Retrieval	39331791188	28.39061	-178.28265	No Data	No Data	19.20
STR	Deployment	3939038-1860	28.39061	-178.28265	29-Sep-08	Logging	19.20
WTR	Retrieval	26P390371071	28.45154	-178.35624	16-Sep-06		18.59
WTR	Deployment	26P390371071	28.45154	-178.35624	29-Sep-08	Logging	18.59
STR	Retrieval	39331791190	28.45154	-178.35624			18.59
STR	Deployment		28.45154	-178.35624	29-Sep-08	Logging	18.59



## Preliminary Mooring Results

The five STRs, one SBE37 and two WTRs recovered from Kure yielded usable data sets (Fig. G.1.2.). Between September 2006 and September 2008, subsurface water temperatures around Kure fluctuated with seasonal variability typical for these latitudes; lows occurring between January and March ( $\sim 18^\circ\text{C}$ ) and highs between August and October ( $\sim 28^\circ\text{C}$ ). Shallower instruments showed larger diurnal fluctuations than those in deeper waters due to daily solar heating and cooling. Brief salinity drops are likely due to heavy rainfall and subsequent influx of freshwater to the surface waters (Fig. G.1.2.).

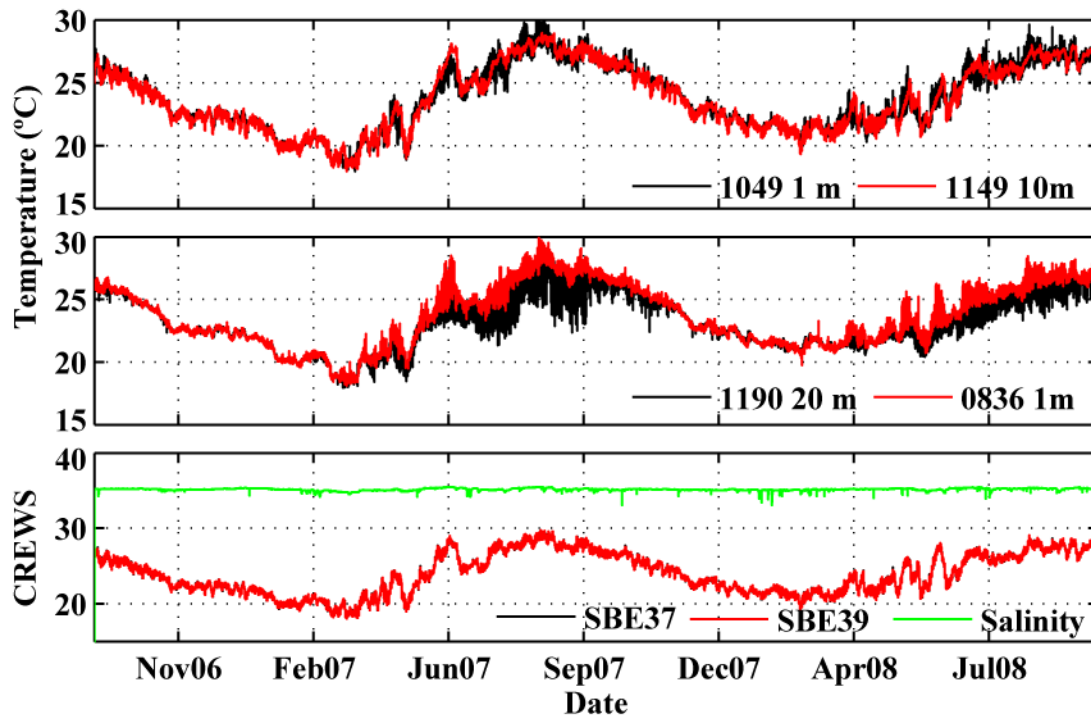


Figure G.1.2.--Temperature and salinity data obtained from five STRs and one SBE37 around Kure Atoll.

## Water Quality:

Thirteen shallow water conductivity, temperature and depth (CTD) casts were conducted at the 30-m bathymetric contour around Kure Atoll at approximately 2-nautical mile (nmi) intervals using a Seabird 19+ with additional dissolved oxygen (DO) and transmissometer sensors attached (Fig. G.1.3.). All of the shallow-water CTD casts on the outside of the atoll were conducted on September 30, 2008, and the one in the center of the lagoon was conducted on October 1, 2008. Twenty one discrete water samples, collected concurrently with shallow-water CTD casts, were taken at five of the shallow water CTD sites using a daisy chain of Niskin bottles at 1 m, 10 m, 20 m and 30 m depth bins. Nutrient and chlorophyll samples were processed and stored according to protocol and will be sent out for analysis following the cruise.

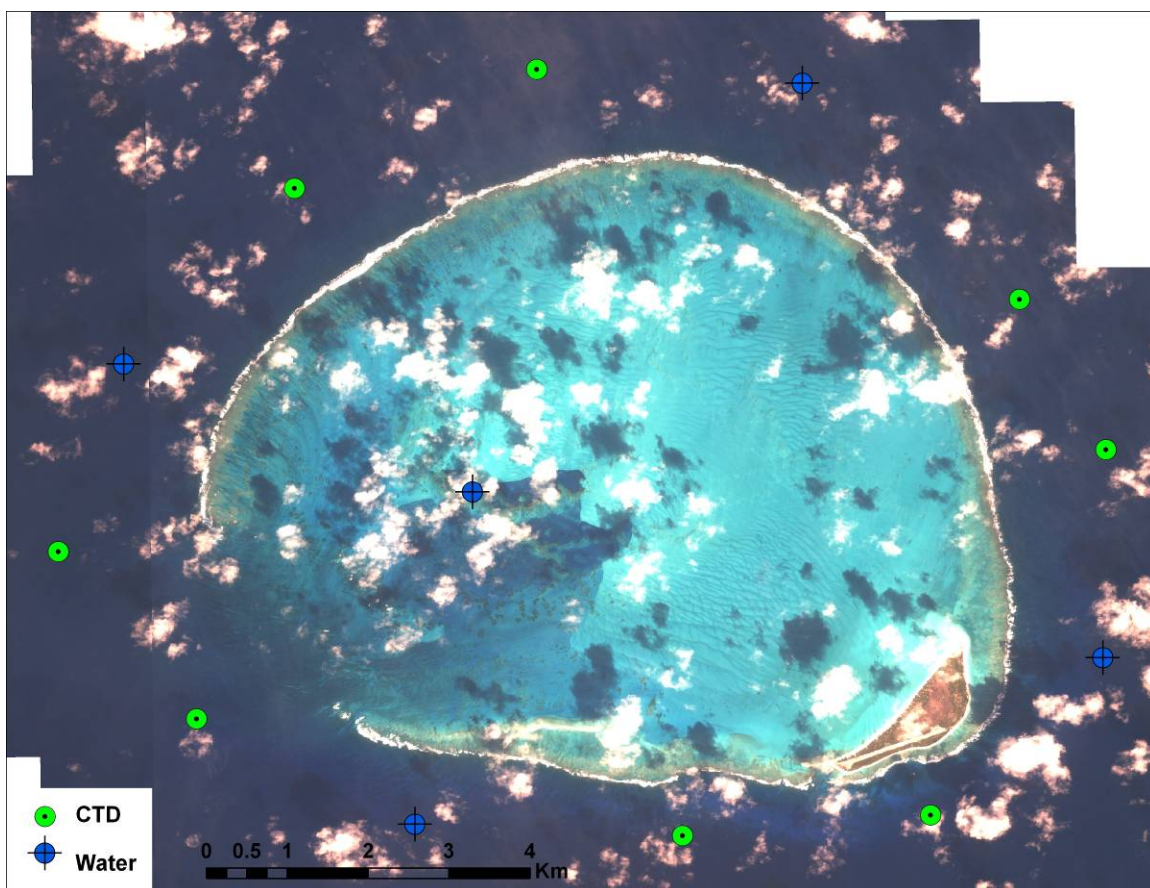


Figure G.1.3.--Shallow-water CTD and water sampling locations around Kure Atoll.

One permanent shipboard CTD site near Kure Atoll was sampled (Fig. G.1.4.). This cast included a CTD profile to 500 m depth, water samples that will be analyzed for chlorophyll and nutrients at the 3 m, 80 m, 100 m, 125 m and 150 m bins, and water samples that will be analyzed for carbonate chemistry (DIC and  $A_T$ ) at the 3 m and 125 m depth bins. The water samples were processed and stored according to protocol and will be sent out for analysis following the cruise.

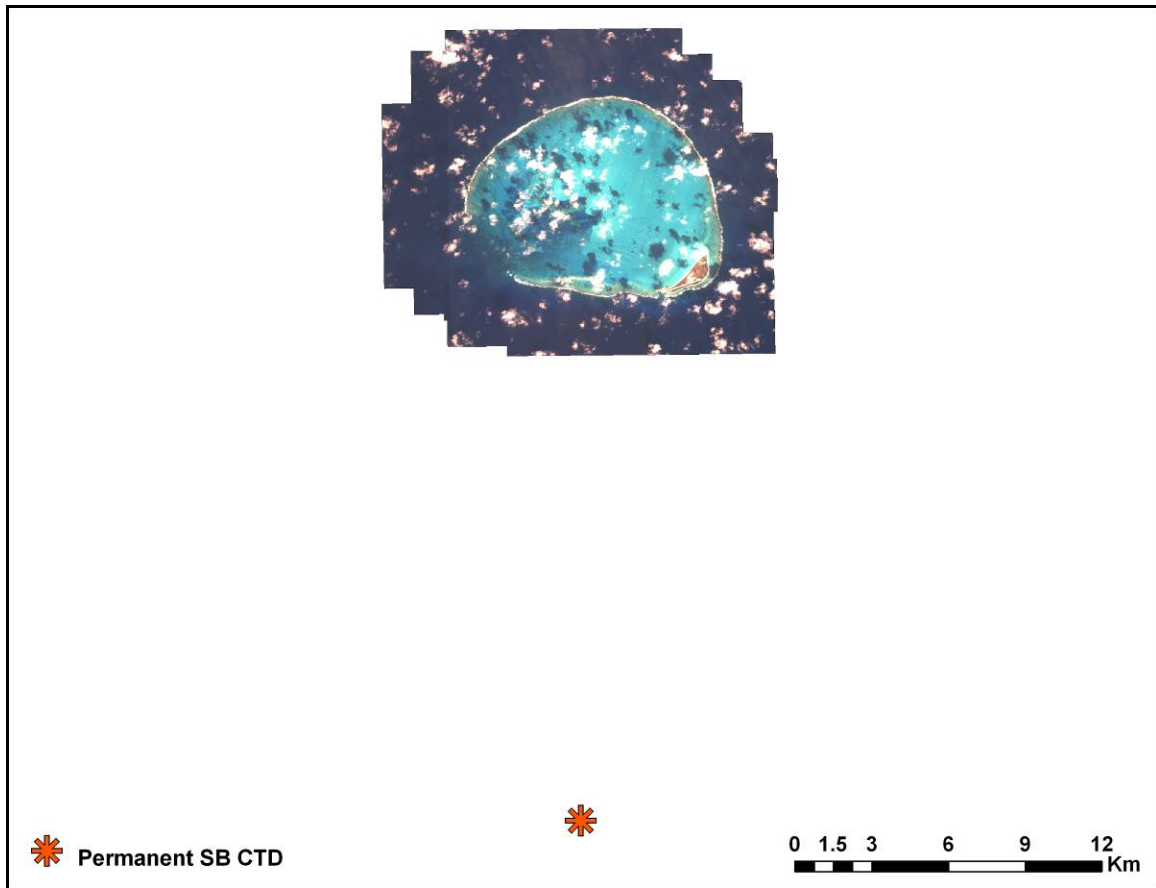


Figure G.1.4.--Permanent shipboard CTD location near Kure Atoll.

## G.2. Rapid Ecological Assessment (REA) Site Descriptions

Twenty-two REA (Rapid Ecological Assessment) surveys were conducted at Kure Atoll between September 29 and October 1, 2008. Nine sites were full REA surveys (benthic and fish) conducted at permanent stations and thirteen were additional sites randomly chosen and surveyed by fish scientists only. At the nine permanent sites, KUR-17 was the only site at which permanent pins were not found (new transect markers were installed). Site locations are plotted in Figure 1, survey dates and efforts are listed in Table 1, and physical and biological characteristics for each site are described below.

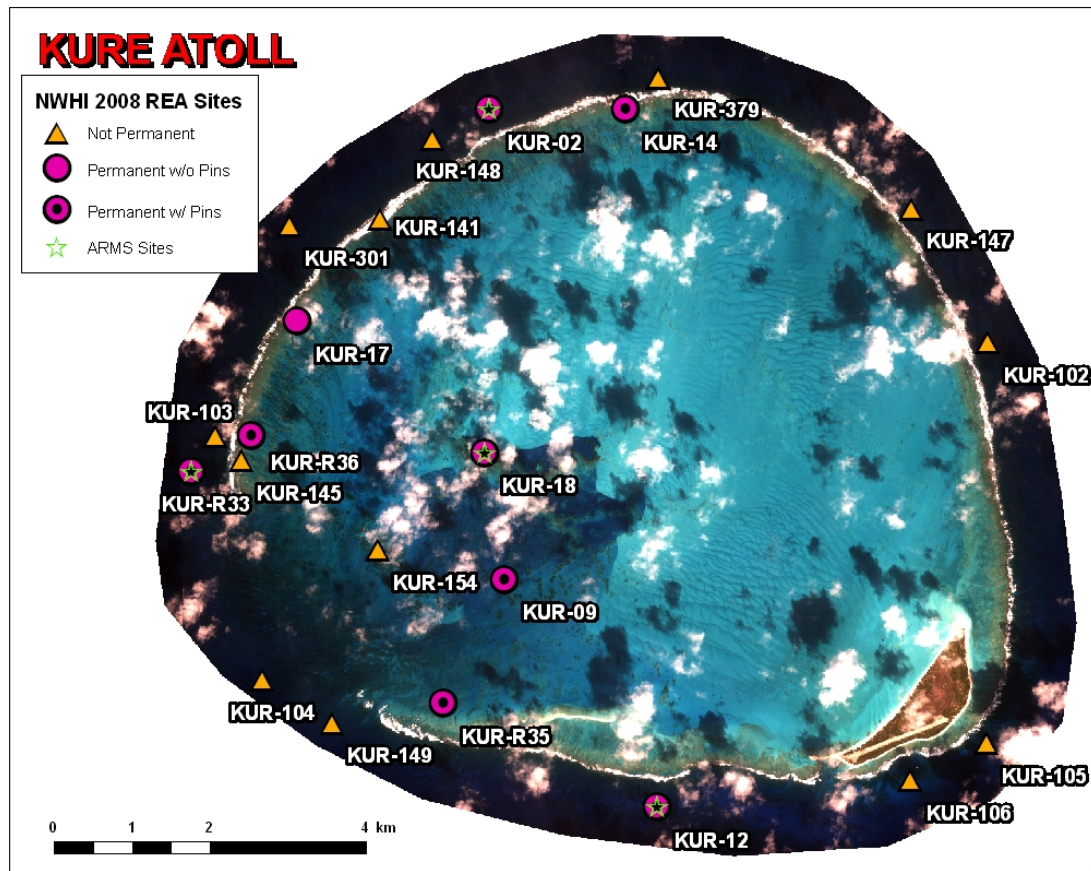


Figure G.2.1.--Kure Atoll 2008 REA site locations.

Table G.2.1.--Kure Atoll survey sites 2008. At each REA site three 25 m × 4 m belt transects (BLT) were performed by the fish team; at each new site two 25 m × 4 m BLTs were performed; unless otherwise noted. Two 25-m transects were sampled by all benthic teams at each site they visited, unless otherwise noted (see also Table A.2.2).

Site	Date	Depth zone	Stratum	REA or New Site	Teams
KUR-145	10/1/2008	Shallow	Backreef	New	Fish
KUR-09	10/1/2008	Shallow	Lagoon	REA	Fish, Coral, Algae, Inverts
KUR-14	10/1/2008	Shallow	Backreef	REA	Fish, Coral, Algae, Inverts
KUR-301	10/1/2008	Deep	Forereef	New	Fish
KUR-141	10/1/2008	Shallow	Backreef	New	Fish
KUR-17	10/1/2008	Shallow	Backreef	REA	Fish, Coral, Algae, Inverts
KUR-103	10/1/2008	Mid	Forereef	New	Fish
KUR-148	10/1/2008	Mid	Forereef	New	Fish
KUR-106	9/30/2008	Mid	Forereef	New	Fish
KUR-154	9/30/2008	Shallow	Lagoon	New	Fish
KUR-12	9/30/2008	Mid	Forereef	REA	Fish, Coral, Algae
KUR-379	9/30/2008	Mid	Forereef	New	Fish
KUR-102	9/30/2008	Mid	Forereef	New	Fish
KUR-147	9/30/2008	Mid	Forereef	New	Fish
KUR-105	9/30/2008	Mid	Forereef	New	Fish
KUR-R35	9/30/2008	Shallow	Lagoon	REA	Fish, Coral, Algae, Inverts
KUR-R33	9/29/2008	Mid	Forereef	REA	Fish, Coral, Algae, Inverts
KUR-149	9/29/2008	Mid	Forereef	New	Fish
KUR-104	9/29/2008	Mid	Forereef	New	Fish
KUR-R36	9/29/2008	Shallow	Backreef	REA	Fish, Coral, Algae, Inverts
KUR-18	9/29/2008	Shallow	Lagoon	REA	Fish, Coral, Algae, Inverts
KUR-02	9/29/2008	Mid	Forereef	REA	Fish, Coral, Algae, Inverts



## Site Descriptions:

September 29, 2008

### KUR-R33

Western forereef, Depth Range: 13.6–15.9 m

Spur-and-groove habitat, used permanent transect pins installed in 2006; pins ran along the top of the spur; installed three autonomous reef monitoring systems (ARMS).

Benthos was dominated by turf algae colonized on pavement and dead coral (41.2%). Coral cover was moderately low (14.8%) composed mostly of *Pocillopora* sp. (recorded as *P. meandrina* based on prior records of Jean Kenyon and Bernardo Vargas-Angel; however, colony branches appear thinner and had more irregular verrucae than other colonies of *P. meandrina* seen throughout the archipelago. Macroalgae cover was moderate with *Microdictyon setchellianum* accounting for 22.4% of the substrate. Additional algae documented by the line point intercept (LPI) survey include *Lobophora variegata*, *Dictyota ceylanica*, *Halimeda discoidea*, a species of *Padina*, and crustose coralline red algae. No additional species were documented during the Roving Diver survey. No invert survey was conducted because of the ARMS installment.

Fish abundance and diversity were high, with over 30 species recorded on transect, the most abundant fish being *Stegastes fasciatus*, *Myripristis berndti*, and *Thalassoma duperrey*. Several large *Caranx melampygus* were seen off transect, along with 10 *Pseudocaranx dentex* in the 60–70 cm range. A large *Seriola dumerilii* approximately 120 cm was also observed circling the divers but not approaching with the transect area. Several *Aprion virescens* were in the immediate area as well. A *Pristilepis oligolepis* (squirrelfish) was also seen off transect, with photo documentation.

### KUR-R36

Western backreef, Depth Range: 1.8–3.9 m

Heavily eroded carbonate pavement interspersed with rubble and sand pockets. Used permanent transect pins installed in 2006; pins ran along crest of backreef. Benthos was dominated by turf algae colonized on pavement and rubble (53.6%). Highly epiphytized *Microdictyon setchellianum* was also common (17.6%). Other algal species documented during the LPI survey included *Lobophora variegata* and crustose coralline red algae. No additional algal species were documented during the Roving Diver survey.

Coral cover was moderately low (9.2%) composed of *Porites lobata*, *Pocillopora* sp., *Montipora flabellata*, and *Montipora capitata*. Few cases of *Porites* *Trematodiasis* were observed within transect, however, most colonies in the general vicinity that were greater than 25 cm exhibited moderate levels of the disease. Although colonies of *Montipora flabellata* appeared healthy, mounds of *Montipora capitata* were bleached and exhibited moderate levels of partial mortality which were being overgrown with algae.

The boring urchins, *Echinostrephus aciculatus* and *Echinometra mathaei*, were the dominant macroinvertebrates. The coral eating snail, *Quoyula madreporum*, and *Calcinus* hermit crabs were common in *Pocillopora* heads. The brittle stars, *Ophiocoma pica* and *Ophiocoma erinaceus*, were abundant.

Fish diversity and abundances at this shallow site were relatively low, though a very large school of surgeonfish (*Acanthurus triostegus* and *A. leucopareis*) were seen off transect. Damsels (*Stegastes fasciolatus*) and wrasse (*Thalassoma duperrey* and *Stethojulis balteata*) were the dominant species. A magnificent snake eel (*Myrichthys magnificus*) glided across the transect; a female cigar wrasse (*Cheilio inermis*) was seen on transect, while the male cigar wrasse waited off transect. Also seen off transect was a single knifejaw.

#### KUR-18

Central lagoon, Depth Range: 3.7 –8.8 m

This site was located on the slope of a *Porites compressa* patch reef (also the former site of the CREWS buoy). Used permanent transect pins installed in 2006 and installed three ARMS. Patch reef was characterized by *Microdictyon setchellianum* (30.4%), blooming *Boodlea composita* (25.6%), and moderately low coral cover (15.2%). Much of the lower sections of *P. compressa* branches were dead or broken (rubble) and covered with turf algae (18%). Outside of the survey area, some interesting colonies of *Pavona varians* were observed at the base of the coral mounds exhibiting a unique morphology.

Additional macroalgae documented during the LPI survey included a relatively high abundance of *Dictyosphaeria versluysii* (5.2%) and crustose coralline red algae. *Dictyosphaeria cavernosa*, *Halimeda discoidea*, *Lobophora variegata*, and a species of *Galaxaura* were documented during the Roving Diver survey.

The sea cucumber, *Actinopyga obesa*, was the dominant macroinvertebrate followed by *Bohadaschia paradox*. Both were draping over the *Porites compressa*. The species, *Holothuria atra* and *H. whitmaei* were prevalent off transect in the sand. With the exception of these holothuroids, macroinvertebrates were uncommon.

Fish diversity and abundance were relatively low, with the exception of a few species. A large school of approximately 200 *Mulloidichthys flavolineatus*, and *M. vanicolensis* in the 13–15 cm range was mostly off transect, with a portion of the school being counted in replicate C. A school of *Kyphosidae* numbering in the hundreds was seen off transect as well, with an average length of 25 cm. Most fish counted on transect were juveniles from many species, to include *Thalassoma duperrey*, *Acanthurus triostegus*, and *Stegastes fasciolatus*.

#### KUR-104

N 28° 23.721 W 178° 22.215

Southwestern forereef, Depth: 20 m

Site 104 is located on the southwestern forereef on spur-and-groove substrate. It was established by the REA fish team as a new sampling location in the moderate forereef stratum. Rugosity and coral cover were very low at this spur-and-groove site, but several overhangs and small pinnacles were present in the immediate area. Visibility was poor at only 40 feet, and a light current (0.2 kts) was present as well. Fish diversity seemed to be on the lower end, but could not be completely determined because of the presence of a very large school (approximately 200) of *Caranx melampygus*. Ranging from 50–80 cm, their presence spooked most of the smaller fish in the area into hiding and were not seen for the remainder of the survey. From the species that were counted, *Chromis hanui*, *C. vanderbilti*, and *C. ovalis* were the most abundant. At least two *Carcharhinus galapagensis* were observed off transect as well.

#### KUR-149

N 28° 21.729', W 178° 21.729'

Southwestern forereef, Depth: 11 m

This site is on the southwestern forereef of Kure Atoll. It was established by the REA fish team as a new sampling location in the forereef moderate stratum. Coral cover was moderate at this spur-and-groove site, with ~ 40% *Pocillopora meandrina* sprinkled with the occasional patch of *Porites lobata*. One moderate-sized Galapagos shark appeared on transect, while several others patrolled the adjacent sand channels. *Thalassoma duperrey* again dominated the smaller fish populations, while *Naso unicornis*, *Chlorurus perspicillatus*, and *Bodianus bilunulatus* comprised the larger fish. Of note off transect were sightings of *Oplegnathus punctatus*, *Caranx dentex*, and a single *Sphyaena barracuda*.

#### September 30, 2008

#### KUR-02

Northern forereef, Depth Range: 12–13 m

Spur-and-groove habitat, used permanent transect pins installed in 2006; pins ran along the top of the spur; installed three ARMS. Benthos was dominated by highly grazed *Microdictyon setchellianum* (28.8%) and moderate coral cover (28%) composed mainly of *Pocillopora* sp. A large percentage of *Pocillopora* colonies exhibited compromised health states and a few cases of *Porites* Trematodiasis were also seen. In addition, numerous colonies of *Palythoa* sp. consisting of only 1–5 polyps were observed as well as an interesting case of an unknown coralline algae disease.

Additional algal species documented in the LPI survey included *Laurencia galtsoffii*, *Lobophora variegata*, crustose coralline red algae, *Turbinaria ornata*, *Halimeda discoidea*, and a species of *Padina*. Non-geniculate coralline red algae, and species of *Jania*, *Sargassum*, *Neomeris*, and *Galaxaura* were documented during the Roving Diver survey.

The coral eating snail, *Quoyula madreporum*, *Calcinus* hermit crabs, trapezid crabs, and the urchins, *Echinostrephus aciculatus* and *Echinometra mathaei*, were abundant. *Linckia multifora* and the coral crab, *Pseudoliomera speciosa*, were common. The polychaete, *Spirobranchus giganteus*, and the brittle star, *Ophiocoma pica* were widespread.

Fish diversity and abundance of the species were low. Species that were most numerous include *Stegastes fasciolatus*, *Plectroglyphidodon johnstonianus*, and *Thalassoma duperrey*. One *Seriola dumerili* approximately 120 cm was seen near the transect and a few *Aprion virescens* in the distance. One *Carcharhinus galapagensis* was also seen briefly off transect.

#### KUR-R35

Southern lagoon, Depth Range: 3.6–4.5 m

Moderately eroded carbonate pavement interspersed with rubble and sand. Used permanent transect pins installed in 2006.

The benthos was dominated by *Microdictyon setchellianum* (28%) and a species of *Sargassum* (28%) and sand with turf algae. Small patches of *Boodlea composita* were also documented during the LPI survey as well as relatively low percent cover of *Halimeda discoidea*, *Dictyota ceylanica*, *Lobophora variegata*, and crustose coralline red algae. No additional species were documented during the Roving Diver survey.

Coral cover was low (1.6%) composed almost entirely of *Pocillopora* heads. Many colonies exhibited partial mortality. Only two other coral species were seen in the area: *Cyphastrea ocelina* and *Porites lobata*.

The dominant macroinvertebrate was the boring urchin, *Echinometra mathaei*. *Calcinus* hermit crabs, the coral eating snail, *Quoyula madreporarum*, and the urchin, *Echinostrephus aciculatus*, were common.

Diversity and abundance of fish were relatively low. Small wrasses were the most abundant fish encountered on the transect, to include *Thalassoma duperrey*, *T. ballieui*, and *Coris venusta*. A school of approximately 20 *Naso unicornis* 40–50 cm long was seen off transect with 3 adult *Oplegnathus punctatus*. Larger species on transect included *Bodianus bilunulatus* at 25 cm, *Coris flavovittata* at 40 cm, and *T. ballieui* at 35 cm.

#### KUR-12

Southern forereef, Depth Range: 9–12.5 m

This site was located along the top of a spur with deep sand channels on either side. Used permanent transect pins installed in 2006 and installed three ARMS.

The benthos was dominated by macroalgae with highly epiphytized *Microdictyon setchellianum* (27.6), *Stypopodium flabelliforme* (15.2) most common. Coral cover was moderate (15.2%) dominated by *Pocillopora* sp. with many colonies having broken tips likely from predation. *Porites lobata* colonies were also present and several cases of trematodiasis observed within the survey area.

Additional algal species documented by the LPI survey included *Distromium flabellatum*, turf algae, *Lobophora variegata* and *Laurencia galtsoffii*, *Halimeda discoidea*, *Dasya iridescens*, and crustose coralline red algae. *Turbinaria ornata*, *Sargassum echinocarpum* and a species of *Jania* were documented during the Roving Diver survey.

The boring urchins, *Echinostrephus aciculatus* and *Echinometra mathaei*, were the dominant macroinvertebrates. *Calcinus* hermit crabs, trapezid crabs, the coral eating snail, *Quoyula madreporarum*, and the sea cucumber, *Holothuria atra*, were common.

Fish diversity and abundance were moderate in species less than 20 cm. Fish, 20 cm and larger, were not very abundant, with *Chlorurus perspicillatus*, *Myripristis berndti*, and *Naso unicornis* being the most numerous species. Smaller species that were most common included *Thalassoma duperrey*, *Cirrhitops fasciatus*, *Centropyge potteri*, and *Chromis vanderbilti*. Three large (100–120 cm) *Seriola dumerili* were seen off transect, as well as a few *Aprion virescens*, and one *Sphyrnaena barracuda* 150 cm in length.

#### KUR-106

N 28° 23.105 W 178° 17.726

Southern forereef, Depth: 9 m

This site is located in the southern forereef of Kure Atoll. It was established by the REA fish team as a new sampling location in the moderate forereef stratum. This site contained moderate spur-and-groove patches with large areas of sand. The substrate was composed of bare rock with some sand covering. Approximately 5% *Porites lobata* and 1% *Pocillopora* comprised the live coral portions of the transects. As with site 105, diversity was moderate but abundances of fish were low. The most common fishes were *Stegastes fasciolatus* and *Thalassoma duperrey*. Off transect sightings included two large *Seriola dumerili*, a group of large *Naso unicornis* and a *Xanthichthys mento*.

#### KUR-105

N 28° 23.332 W 178° 17.202

Southern forereef, Depth: 11 m

This site is located in the southern forereef of Kure Atoll. It was established by the REA fish team as a new sampling location in the moderate forereef stratum. The site was composed of large spur-and-groove patches composed of pavement rock. Coral cover was sparse, with less than 5% *Porites lobata* and less than 1% *Pocillopora*. The dominant substrate was crustose coralline algae and bare rock, with lots of filamentous algae. The site contained moderate diversity but low abundances of fish. The most common fishes included *Thalassoma duperrey* and *Stegastes fasciolatus*. There were no large off transect sightings, but we did find a leopard moray swimming across the transect on the small fish counts. Two crown-of-thorns starfish were present in the area.

KUR-379

N 28° 27.403 W 178° 19.470

Northern forereef, Depth: 8.5 m

This site was located on the northern forereef in spur-and-groove habitat. It was established by the REA fish team as a new sampling location in the moderate forereef stratum. The tops of the spur were flat and had low relief, with scattered *Pocillopora* heads at 40% coral cover and low algal cover. The grooves were steep with ledges/caves, and high relief. There was a large school of about 200 *Acanthurus leucopareius* at 15 cm that was mixed with *Acanthurus nigrofuscus*, and *Acanthurus triostegus*. *Thalassoma duperrey* was omnipresent, as usual. A large ulua (*Caranx ignobilis*) was recorded on transect. Knifejaws were seen off transect and three large *Aprion virescens* were in the area, as was a small Galapagos reef shark.

KUR-147 9/30/08

N 28° 26.601 W 178° 17.719

Northeastern forereef, Depth: 10.3 m

This site was located on the northeastern forereef and consisted of spur-and-groove habitat. It was established by the REA fish team as a new sampling location in the moderate forereef stratum. The tops of the spurs were relatively flat and the grooves were steep with ledges, overhangs, and caves with high relief. Scattered *Pocillopora* heads and encrusting *Porites lobata* were the dominant corals at 30 to 20% coral cover. There were lots of Kyphosids at this site with about 100–150 individuals at 20–40 cm off transect and several schools of Kyphosids swimming through the transect lines. Though not confirmed, there were possible sightings of the blackedge nibbler (*Girella leonina*), a subfamily of Kyphosidae. This shy fish is rarely seen in the Northwestern Hawaiian Islands, but was recently recorded at Midway (Randall and Stender, 2002). There were several knifejaws in the grooves and caves at this site. There were also several *Naso unicornis* off transect at 40 and 50 cm.

KUR-102

N 28° 25.782 W 178° 17.190

Eastern forereef, Depth: 10 m

This site was located on the eastern forereef of Kure and consisted of spur-and-groove habitat. It was established by the REA fish team as a new sampling location in the moderate forereef stratum. The tops of the spurs were relatively flat and the grooves were steep with ledges, overhangs, and caves with high relief. Transect A had more coral cover at 30% than B at 2%. *Pocillopora* and encrusting *Porites lobata* were the dominant corals on transect A. There were lots of *Myrpristis* spp. under the ledges. There were two *Goniistius vittatus* off transect at 22 and 28 cm. There were also several knifejaws, large *Parupeneus porphyreus*, and two *Calotomus zonarchus* at 25 and 30 cm.

KUR-154

N 28° 24.514 W 178° 21.416

Western lagoon, Depth: 3 m

This site was a patch reef with rubble sides located in the western lagoon of Kure. It was established by the REA fish team as a new sampling location in the shallow lagoon

stratum. The beginning of transect A was 100% algal cover composed entirely of *Boodlea*. Coral cover was less than 1%, and turf algae dominated the substrate for the second half of transect A and all of transect B. A very large school of Kyphosids darted through the transect, trying to distract the divers from counting the confusing array of juvenile fish milling about on the edge of the surge zone. A single knifejaw was counted, while several others hovered off transect. Three *Scombroides laysan* were located off transect at 57 and 53 cm.

October 1, 2008

KUR-17

Western backreef, Depth Range: 0.9–3.6 m

Carbonate pavement with dead coral surfaces moderately to heavily bioeroded. Permanent transects installed by Greta Abey in 2005 were not used due to some miscommunication. New permanent transects were installed (three pins at each of two 25-meter transects, with two pins marking the beginning of the transect and one pin marking the end; transects were not laid back to back, rather the first transect was laid with a bearing of 045° and the second transect was laid with a heading of 060°), and two new global positioning system positions were recorded for the start of each transect.

Benthos dominated by turf-colonized pavement, small, possibly highly grazed, individuals of *Microdictyon setchellianum* and moderately low coral cover (10.8%). Benthic composition was extremely diverse within the two transects, with the first transect and most of the second transect consisting of mostly carbonate terrain which was heavily bioeroded. The first 8 meters of transect two were dominated by encrusting *Montipora capitata* which had considerable partial mortality and had large encrusting colonies of *Montipora flabellata*, as well as *Pocillopra* sp. and *Psammocora stellata* growing within the former *M. Capitata* colonies which contributed to the elevated coral cover.

Additional algal species documented on the LPI survey included crustose coralline red algae, *Lobophora variegata* and individuals of *Laurencia galtsoffii* and *Stypopodium flabelliforme* while a species of *Sargassum* and *Halimeda discoidea* were documented on the Roving Diver survey.

The boring urchins, *Echinostrephus aciculatus* and *Echinometra mathaei*, and the sea cucumber, *Actinopyga obesa*, were the dominant macroinvertebrates. The urchin, *Heterocentrotus mammilatus* was common and the sea cucumber, *Holothuria atra*, and coral snail, *Quoyula madreporarum*, were occasional. The brittle star, *Ophiocoma pica*, was abundant.

Fish diversity was moderate at this site, with larger fish such as *Naso unicornis*, *Thalassoma ballieui*, and *Kyphosids* being the most abundant. Wrasses such as *T. duperrey*, *Coris venusta*, and the damselfish *Stegastes fasciolatus* were the most abundant fish under 20 cm. One *Caranx ignobilis* and *Carcharhinus galapagensis* was also seen briefly off transect at the beginning of the survey.

#### KUR-14

Northern backreef, Depth Range: 0.9–1.5 m

Carbonate pavement heavily bioeroded and interspersed with rubble and sand pockets. Used permanent transects installed by Greta Abey in 2005. Site consisted of several large mounds of *Porites lobata* and scattered *Pocillopora* colonies. Benthos dominated by turf-colonized pavement (42.8%) and small individuals of *Microdictyon setchellianum* (14%) and *Laurencia galtsoffii* (14.8%).

Coral cover was 10% with richness relatively high for a backreef site with eight scleractinian species enumerated within the survey area. Interestingly, a colony of *Pavona maldivensis* was observed growing under an overhang from an old *Porites* head. Several cases of trematidiasis were detected on colonies of *Porites lobata* within transect segments; however, the majority of colonies in the area were suffering from mild to severe cases. A moderately sized rope entanglement which had toppled several *Pocillopora* heads was seen crest-ward of the permanent transects.

Other algal species documented on the LPI Survey included crustose coralline red algae and *Lobophora variegata*, while a species of *Sargassum*, non-geniculate coralline red algae, *Dictyosphaeria versluysii* and *Halimeda discoidea* were documented on the Roving Diver survey.

The boring urchins, *Echinostrephus aciculatus* and *Echinometra mathaei*, and the sea cucumber, *Actinopyga obesa*, were the dominant macroinvertebrates. The coral snail, *Quoyula madrepোরারum*, was common and the sea cucumber, *Holothuria atra*, was occasional on transect but prevalent off transect.

Fish diversity was relatively low at this location, but fishes present were in abundance. A school of approximately 100 *Acanthurus triostegus* and 50 *A. leucopareius* were recorded on replicate C. Wrasses such as *Thalassoma duperrey*, *T. ballieui*, and *Coris venusta* were also in abundance. Large *Naso unicornis* and *Chlorurus perspicillatus* were seen off transect.

#### KUR-09

Central lagoon, Depth Range: 3.4–6.7 m

Lagoon patch reef composed of carbonate surfaces and large patches of rubble and sand. Used permanent transect pins installed in 2006 which ran along the base of patch reef. Benthos dominated by *Boodlea composita* (48%), turf algae (24.4%).

Corals were extremely depauperate, with the LPI survey tallying 0 for percent cover. *Pocillopora meandrina* and *P. damicornis* were the most common corals with many of the *P. meandrina* colonies exhibiting compromised health states with dead portions overgrown with algae.



Other algal species documented by the LPI Survey included *Lobophora variegata*, *Microdictyon setchellianum*, *Stypopodium flabelliforme*, and crustose coralline red algae, while *Halimeda discoidea*, *Dictyota ceylanica*, a species of *Chrysomenia*, and *Chondrophycus parvipapillatus* were documented during the Roving Diver survey.

The boring urchin, *Echinometra mathaei*, and the sea cucumber, *Actinopyga obesa*, were common. The sea cucumber, *A. obesa*, was observed eating the invasive *Boodlea*. Due to the coverage of *Boodlea* on the habitat, counts of urchins were probably low to actual numbers.

Fish diversity was moderate with wrasses being the most abundant fish along with *Stegastes fasciatus* and *Dascyllus albisella*. Uncommon species encountered include two *Pterois sphex* and one thornback cowfish (*Lactoria fornasini*).

#### KUR-148

N 28° 27.029 W 177° 21.033

Depth: 9 m

This site was located on the fore reef at mid depth, and consisted of spur-and-groove habitat. The tops of the spurs were relatively flat with moderate complexity and relief with *Pocillopora* spp., and encrusting *Porites lobata* were scattered on the spurs at 60% coral cover. The grooves were steep with deep ledges, overhangs, and caves with high relief. There were several species of hawk fishes; *Cirrhitus pinnulatus*, *Paracirrhites arcatus*, *P. forsteri*, and *Cirrhitops fasciatus*, and a high quantity of *Thalassoma duperrey*. There were knifejaws, *Calotomus zonarchus*, and *Goniistius vittatus* off transect.

#### KUR-301

N 28° 26.498 W 178° 22.024

Northwest forereef, Depth: 20 m

This site was located on the northwest forereef of Kure. It was established by the REA fish team as a new sampling location in the deep forereef stratum and was similar in spur-and-groove topography at site 148.. The tops of the spurs were relatively flat with moderate complexity and relief with *Pocillopora* spp., and encrusting *Porites lobata* were scattered on the spurs at 60% coral cover. The grooves were steep with deep ledges, overhangs, and caves with high relief. Fish diversity and abundance were moderate, with few large fish on transect. . Seen off transect was one *Carcharhinus galapagensis* at 6 ft., *Goniistius vittatus*, and one *Seriola dumerili* at 70 cm.

#### KUR-103

N 28° 25.210 W 178° 22.539

Western forereef, Depth: 8 m

This site was located on the western forereef in mid depth. It was established by the REA fish team as a new sampling location in the moderate forereef stratum. The habitat was spur and groove, and there were ledges with many overhangs and caves. The grooves were wide and covered in rubble and boulders. *Pocillopora* and *Pavona duerdeni* corals were the most dominant of the 50% coral cover. Relief and habitat complexity were

moderate on the spurs and high in grooves because of the caves and overhangs. The overhangs held a high number of *Myripristis* spp. There were two *Carcharhinus galapagensis*, one *C. amblyrhynchos*, and two *Aprion virescens* off transect. A large school of acanthurids was located off transect with 100 *Acanthurus leucopareius* at 16–18 cm and 66 *A. triostegus* at 15 cm.

#### KUR-141

N 28° 26.539 W 178° 21.400

Northern backreef, Depth: 1 m

This site was located on the northern backreef of Kure. It was established by the REA fish team as a new sampling location in the shallow backreef stratum. The habitat consisted of patches of coral, encrusting *Porites lobata*, *Pocillopora* spp., and *Montipora flabellata* at 50% coral cover. Turf algae were also prevalent at this site. Rubble and sand were lodged in between the coral patches. This site hosted a large number of wrasses; *Thalassoma dupery*, *T. purpureum*, *Bodianus bilunulatus*, *Gomphosus varius*, *T. ballieui*, *Stethojulis balteata*, *Macropharyngodon geoffroy*. There were also several species of acanthurids in the area: *Acanthurus leucopareius*, *A. triostegus*, *A. nigrois*, and *Ctenochaetus strigosus*. There were very few scarids and almost no scarid juveniles.

#### KUR-145

N 28° 25.062 W 178° 22.358

Western backreef, Depth: 1 m

This site was located on the western backreef in 1 meter of water. It was established by the REA fish team as a new sampling location in the shallow backreef stratum. The site was flat with low relief and scattered *Pocillopora* heads at low coral cover off 2%. Turf algae and coralline algae were present. The dominant fish were *Thalassoma dupery* and *Stethojulis balteata*. There were two *Caranx melampygus* at 50 to 60 cm off transect.

### G.3. Benthic Environment

#### G.3.1. Algae

Benthic communities around Kure Atoll were dominated by macro- and turf algal functional groups (Table G.3.1.1.). A combined total of 14 species of macroalgae were observed (4 chlorophytes, 5 ochrophytes, 5 rhodophytes) from the 9 sites surveyed (Tables G.3.1.2., G.3.1.3.). Individuals of *Microdictyon setchellianum* were the most prevalent species encountered and covered 8.8% to 30.4% of the substrate across all sites (Table G.3.1.3.). Plants often formed a continuous, dense mat over the seafloor, generally were highly colonized with epiphytes, and sometimes showed evidence of high grazing activity. A dense, mat-forming green algae, *Boodlea composita*, was also common at three of the nine sites surveyed and covered 5.6% to 48% of the substrate at these sites (Table G.3.1.3.). A bloom of this species is known to be occurring at Midway Atoll where it is the dominant benthic cover across large areas of the Atoll (Vroom et al.). *Lobophora variegata* was documented at eight of the nine sites surveyed and ranged in percent cover from 2 to 10% at these sites. A species of *Sargassum* covered over 28%

of the seafloor at KUR-R35, but was a minor component of the algal community at other sites (Table G.3.1.3.).

Table G.3.1.1.--Percent cover of algal functional groups at long-term monitoring sites at Kure Atoll.

Site	Macroalgae	Turf algae	Coralline red algae (crustose + upright)	Cyanobacteria
KUR-02	46.8%	18.0%	6.0%	-
KUR-09	65.2%	24.4%	6.8%	-
KUR-12	64.4%	17.2%	3.2%	-
KUR-14	31.2%	51.2%	4.8%	-
KUR-17	21.2%	53.6%	8.0%	-
KUR-18	61.2%	18.0%	0.4%	-
KUR-R33	36.4%	41.2%	7.2%	-
KUR-R35	66.4%	26.0%	4.8%	0.4%
KUR-R36	22.4%	53.6%	4.4%	-

Table G.3.1.2.--Additional species recorded at each site at Kure Atoll during Roving Diver surveys.

Site	<b>Chlorophyta</b>
KUR-18	<i>Dictyosphaeria cavernosa</i>
KUR-14	<i>Dictyosphaeria versluysii</i>
KUR-09, KUR-14 KUR-17, KUR-18	<i>Halimeda discoidea</i>
KUR-R35	<i>Neomeris sp.</i>
	<b>Ochrophyta</b>
KUR-09	<i>Dictyota ceylanica</i>
KUR-12	<i>Distromium flabellatum</i>
KUR-18	<i>Lobophora variegata</i>
KUR-12, KUR-14 KUR-17, KUR-R35	<i>Sargassum sp.</i>
KUR-12	<i>Turbinaria ornata</i>
	<b>Rhodophyta</b>
KUR-09	<i>Chondrophycus parvipapillatus</i>
KUR-09	<i>Chrysomenia sp.</i>
KUR-18, KUR-R35	<i>Galaxaura sp.</i>
KUR-12, KUR-R35	<i>Jania sp.</i>
KUR-R36	<i>Portieria hornemannii</i>

Table G.3.1.3.--Percent cover of macroalgal species at long-term monitoring sites at Kure Atoll. Sum totals for each row equal the percent cover of macroalgae recorded in Table G.3.1.1.

Site	<i>Boodlea composita</i>	<i>Codium arabicum</i>	<i>Dictyosphaeria cavernosa</i>	<i>Dictyosphaeria versluystii</i>	<i>Halimeda discoidea</i>	<i>Halimeda velasquezii</i>	<i>Microdictyon setchellianum</i>	<i>Dictyota ceylanica</i>	<i>Distromium flabellatum</i>	<i>Lobophora variegata</i>	<i>Padina</i> sp.	<i>Sargassum</i> sp.	<i>Stypopodium flabelliforme</i>	<i>Turbinaria ornata</i>	<i>Dasya iridescens</i>	<i>Laurencia galtsoffii</i>	<i>Portieria hornemannii</i>
KUR-02	-	-	-	-	0.4%	-	28.8%	-	-	6.0%	1.6%	-	-	4.0%	-	6.0%	-
KUR-09	48.0%	-	0.4%	-	-	1.2%	8.8%	-	-	5.2%	-	-	1.6%	-	-	-	-
KUR-12	-	-	-	-	0.8%	-	27.6%	-	4.8%	10.0%	0.4%	-	15.2%	-	0.4%	5.2%	-
KUR-14	-	-	-	-	-	-	14.0%	-	-	2.4%	-	-	-	-	-	14.8%	-
KUR-17	-	-	-	-	-	-	13.2%	-	0.4%	4.4%	-	-	0.8%	-	-	2.4%	-
KUR-18	25.6%	-	-	5.2%	-	-	30.4%	-	-	-	-	-	-	-	-	-	-
KUR-R33	-	0.4%	-	-	1.2%	-	22.4%	2.0%	-	8.4%	0.8%	0.4%	-	0.4%	-	-	0.4%
KUR-R35	5.6%	-	0.4%	-	0.8%	-	28.0%	0.8%	-	2.0%	0.4%	28.0%	0.4%	-	-	-	-
KUR-R36	-	-	-	-	0.4%	-	17.6%	-	-	2.4%	0.8%	0.4%	-	0.8%	-	-	-

### G.3.2. Corals

#### G.3.2.1 Coral Populations

LPI surveys indicate that coral cover at REA sites around Kure in 2008 varied with both habitat and region. Mean coral cover was low inside the lagoon ( $5.6 \pm 4.8\%$ ), slightly higher within the backreef ( $10 \pm .5\%$ ) and highest, although still relatively low, on the forereef ( $19.3 \pm 4.3\%$ ).

Coral community structure varied both between and within habitats. Within the backreef, *Montipora capitata* mounds were present at KUR-17 but not seen at other sites. At the other backreef sites, *Pocillopora* was the most abundant genus, although the northern backreef seems to be dominated by mounding *Porites lobata* and encrusting *M. flabellata* as you move close to the reef crest (permanent transects were not laid in this area).

On the forereef, *Pocillopora* was the dominant coral, especially at site KUR-R33. Interestingly, *Pocillopora* colonies exhibited considerable differences as compared to colonies seen on the forereef in the rest of the archipelago. In 2006, Bernardo Vargas-Ángel also observed this difference, noting that the colonies appear similar to *P. capitata*. In the future, it may be good to collect samples and have a taxonomist determine what species of *Pocillopora* is present.

Within the lagoon, there appears to be two distinct habitat strata, well developed *Porites compressa* patch reefs (KUR-18) and lesser developed *Pocillopora* dominated patch reefs (KUR-09 and R35).

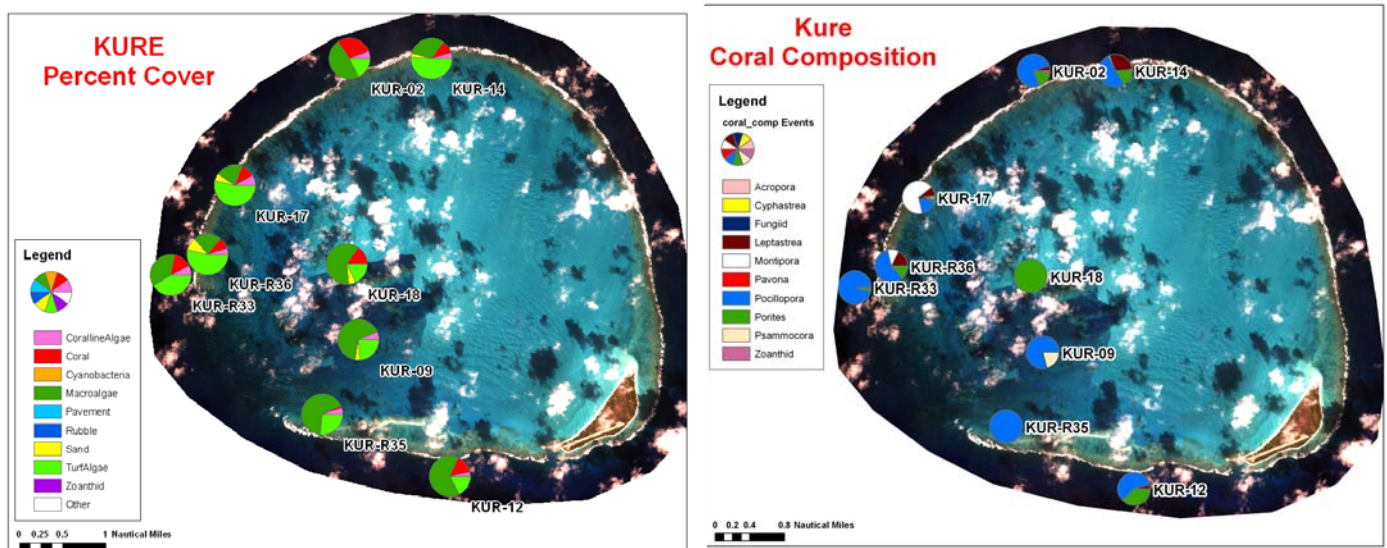


Figure G.3.2.1.1.--Spatial distribution of benthic cover and coral composition for REA sites at Kure in 2008.

Table G.3.2.1.1.--Relative percentage of coral taxon enumerated within belt transects for three habitat strata at Kure in 2008.

Lagoon		Forereef		Backreef	
Taxon	Percent	Taxon	Percent	Taxon	Percent
<i>Porites compressa</i>	77.4	<i>Pocillopora meandrina</i>	75.9	<i>Pocillopora meandrina</i>	33.5
<i>Pocillopora meandrina</i>	18.8	<i>Porites lobata</i>	17.8	<i>Montipora capitata</i>	20.5
<i>Pocillopora damicornis</i>	2.0	<i>Leptastrea purpurea</i>	3.6	<i>Leptastrea purpurea</i>	16.8
<i>Psammocora stellata</i>	0.9	<i>Palythoa</i> sp.	1.7	<i>Montipora flabellata</i>	14.7
<i>Pavona varians</i>	0.4	<i>Pocillopora damicornis</i>	0.6	<i>Porites lobata</i>	8.6
<i>Porites lobata</i>	0.4	<i>Psammocora stellata</i>	0.2	<i>Pocillopora damicornis</i>	2.8
<i>Cyphastrea ocellina</i>	0.1	<i>Pocillopora</i> sp	0.1	<i>Psammocora stellata</i>	1.1
<i>Pocillopora</i> sp	0.0	<i>Cyphastrea ocellina</i>	0.0	<i>Cyphastrea ocellina</i>	1.0
		<i>Pavona duerdeni</i>	0.0	<i>Pocillopora ligulata</i>	0.6
		<i>Porites evermanni</i>	0.0	<i>Fungia scutaria</i>	0.3
		<i>Montipora capitata</i>	0.0	<i>Porites evermanni</i>	0.1
				<i>Pocillopora</i> sp	0.0

#### G.3.2.2. Coral Disease

Overall, corals at Kure Atoll were relatively healthy with the exception of a high prevalence of bleaching in *Montipora capitata* on the forereef, although the majority of these colonies were small and few in numbers. In addition, many colonies of *Pocillopora meandrina* appeared pale and were recorded as bleached; however, this needs to be confirmed by more experienced coral scientists from this area, as the pale color could be a pigmentation response from something other than bleaching. *Porites trematodiasis* was observed in all habitats, but it was most prevalent in the backreef, more specifically in the northern backreef at site KUR-14. Here, the majority of *Porites lobata* colonies exhibited varying levels of disease from mild to severe.

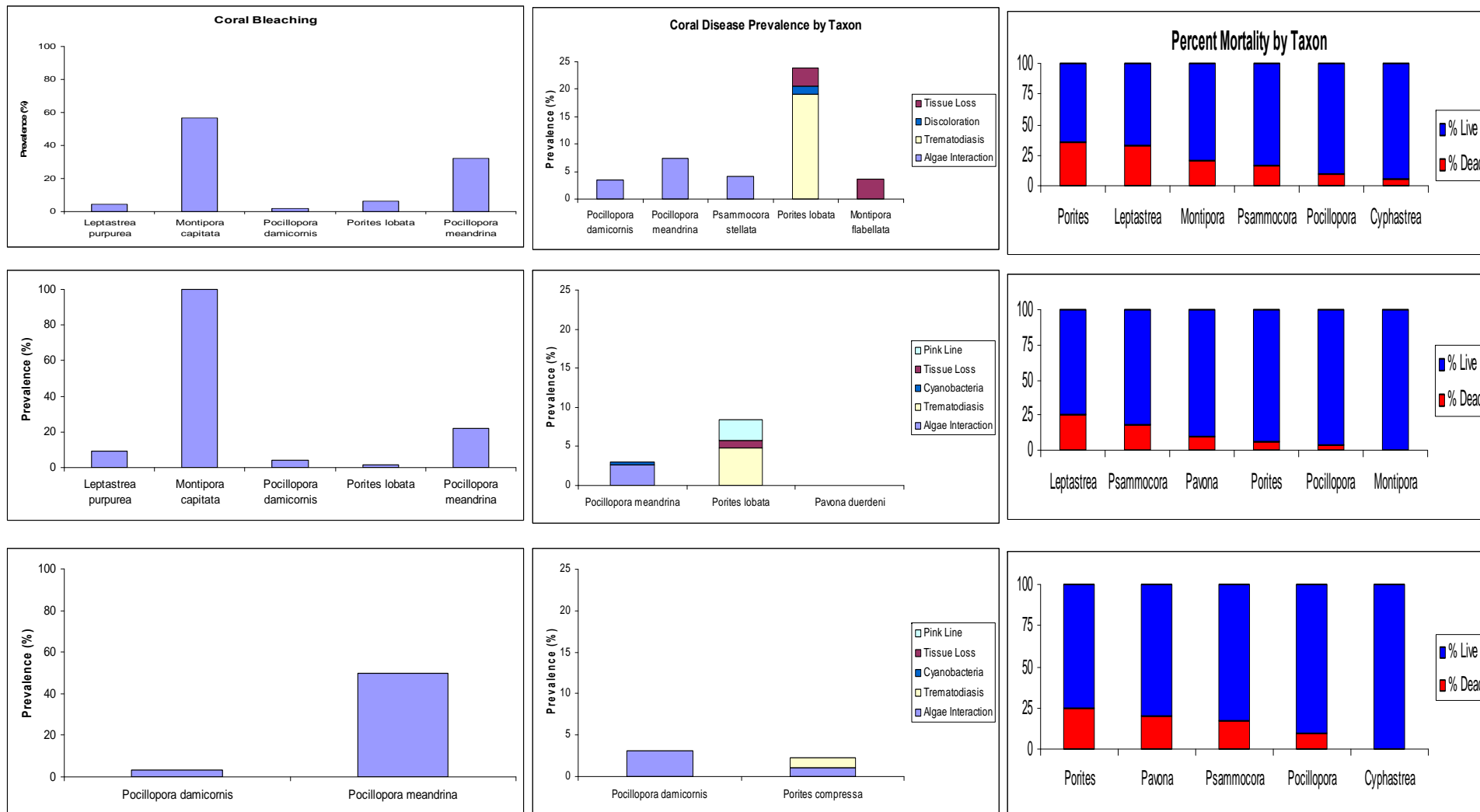


Figure G.3.2.2.1.--Left: Prevalence of bleached colonies for seven taxon at Midway. Middle: Prevalence of coral disease by disease state for eight coral taxon. Right: Relative percent of dead surface area for ten coral genera at Midway. For each group of graphs, the top graph is for the backreef, middle is forereef, and bottom is lagoon.

### G.3.3. Non-coral Invertebrate Surveys

A total of 4375 individuals of benthic invertebrate target species or taxa group were enumerated from 16 belt transects at 8 sites. The sea urchin, *Echinostrephus aciculatus*, was the most abundant benthic invertebrate in forereef sites ( $n = 2$ ) and *Echinometra mathaei* was the most abundant benthic invertebrate in backreef ( $n = 3$ ) and lagoon ( $n = 3$ ) sites (mean density 4.78, 3.84, and 0.63/m<sup>2</sup>, respectively). The forereef site, KUR-12, had the highest density of *Echinostrephus aciculatus* and *Echinometra mathaei* with 6.47/m<sup>2</sup> and 4.78/m<sup>2</sup>, respectively. The forereef site, KUR-02, had high densities of trapezid crabs (0.96/m<sup>2</sup>), the coral eating snail, *Quoyula madreporarum* (0.88/m<sup>2</sup>), *Calcinus* hermit crabs (0.58/m<sup>2</sup>), and the coral crab, *Pseudoliomera speciosa* (0.17/m<sup>2</sup>). *Quoyula madreporarum* was also common at sites KUR-R35 and KUR-14 (0.37 and 0.26/m<sup>2</sup>, respectively). The sea cucumber, *Actinopyga obesa*, was abundant at the lagoon site KUR-18 (0.85/m<sup>2</sup>) and common in the backreef sites KUR-17 and KUR-14 (0.28 and 0.14/m<sup>2</sup>, respectively). At the lagoon site, these sea cucumbers were observed eating the invasive alga, *Boodlea*. The urchin, *Heterocentrotus mammilatus* was common at KUR-17 (0.17/m<sup>2</sup>) and the brittle star, *Ophiocoma pica*, was widespread at KUR-17, KUR-R35, and KUR-02.

#### G.3.3.1. Urchin Measurements

Figure G.3.3.1.1. reveals the average test diameter of urchins encountered at each site. Only sites where  $\geq 5$  measurements were recorded for a species are represented.

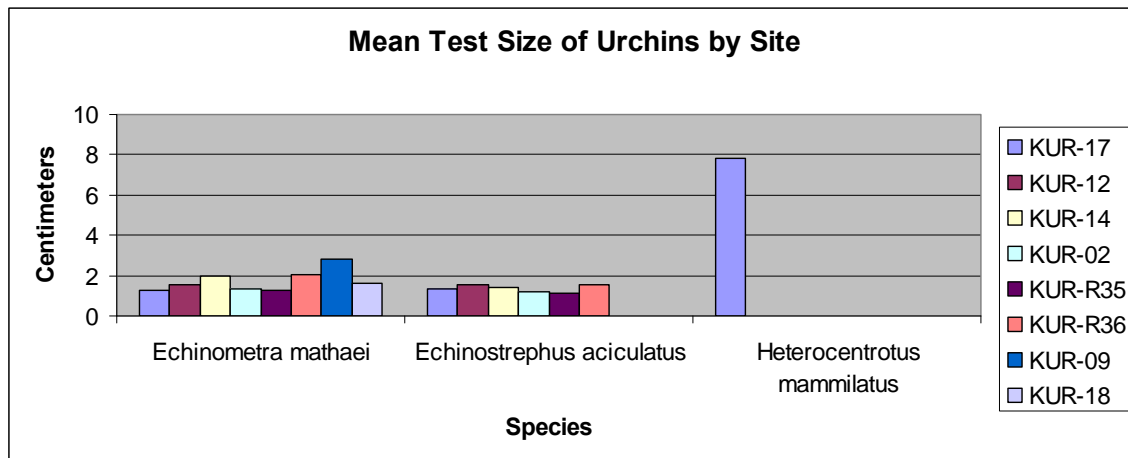


Figure G.3.3.1.1.--Mean test size of urchins by site.



Figure G.3.3.1.2. reveals the average test diameter of urchins by stratum. Only stratum where  $\geq 5$  measurements were recorded for a species are represented.

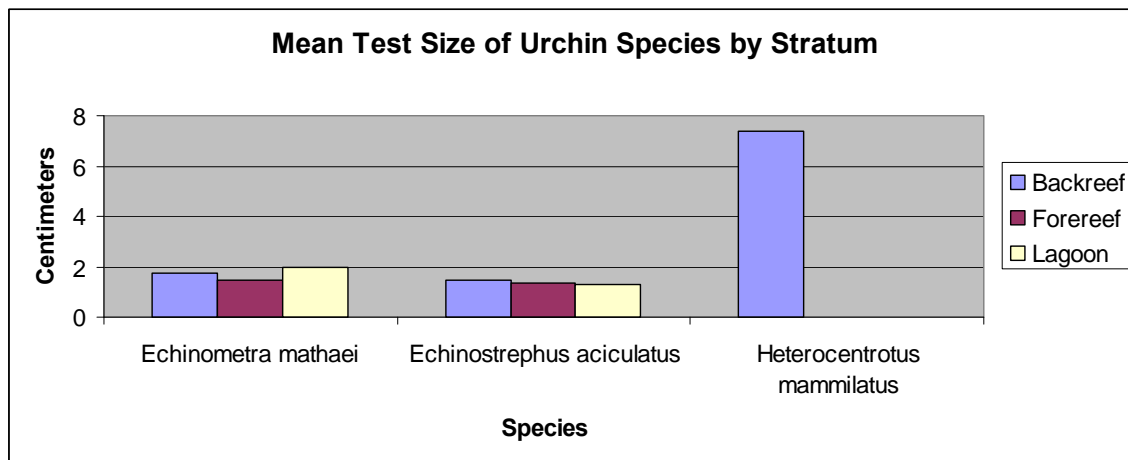


Figure G.3.3.1.2.--Mean test size of urchin species by stratum.

#### G.3.3.2. ARMS Deployment

ARMS were deployed at the following REA sites around Kure. Each site contains three ARMS.

Table G.3.3.2.1.--ARMS deployment locations around Kure Atoll.

REA Site	Latitude	Longitude
KUR-R33	28° 25.006 N	-178° 22.706 W
KUR-18	28° 25.120 N	-178° 20.675 W
KUR-02	28° 27.21798 N	-178° 20.64102 W
KUR-12	28° 22.95102 N	-177° 19.48398 W

#### G.3.4 Towed-diver Benthic Surveys

The 14 towed-diver benthic habitat surveys of Kure Atoll were conducted along the outlying forereef habitat, along with sections of the backreef and a single lagoon tow. The overall averages for substrate composition and macroinvertebrate population densities are illustrated in the tables below (Table G.3.4.1., G.3.4.2.).

Table G.3.4.1.--Overall benthic habitat composition.

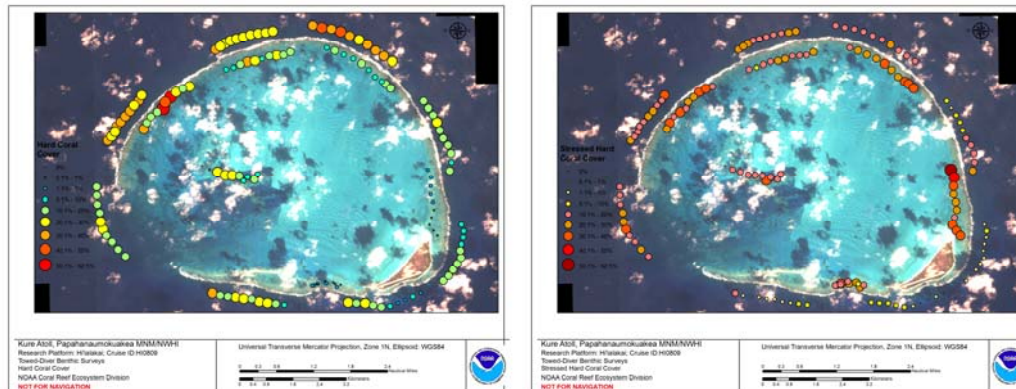
Substrate	Percent Cover (%)	Percent Cover Range (%)
Hard Coral	17.00	0–62.5
Stressed Hard Coral	17.05	0–62.5
Soft Coral	0.34	0–5
Sand	19.19	1.1–75
Rubble	18.05	0–100
Macroalgae	27.98	1.1–100
Coralline algae	6.32	0–30

Table G.3.4.2.--Overall macroinvertebrate population densities.

Macroinvertebrate	Density (#/hectare)	Total # Observed
<i>Acanthaster planci</i> (COTs)	0.008	4
Boring sea urchins	14.24	32,426
Free-living sea urchins	0.02	3
Sea cucumbers	0.89	2126

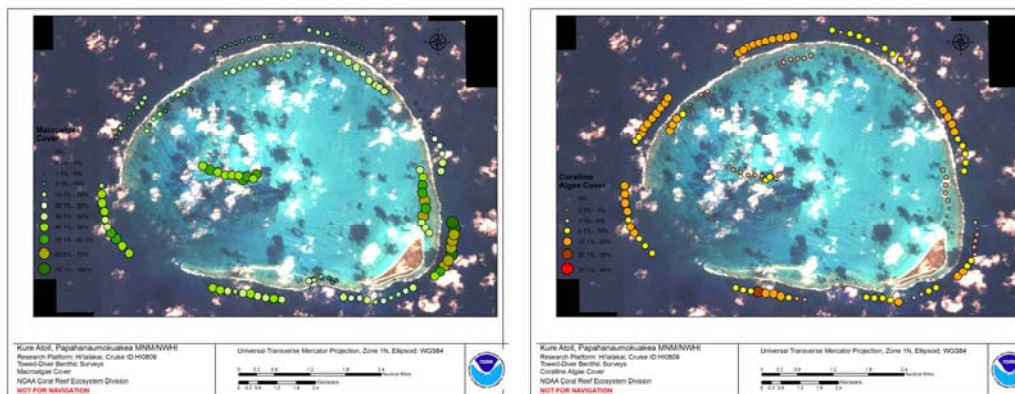
The forereef habitat around Kure Atoll was primarily spur and groove/pavement and pavement reef interspersed with sand flats on all sides of the island. Backreef habitat consisted of a mix between continuous reef, pavement reef, patch reef, and sand and rubble flats. The lagoon survey primarily consisted of continuous reef amongst rubble and sand flats.

Hard coral cover averaged 17% for the entire atoll. The highest coral cover was located along several sections of the northern backreef, where coral composition was primarily composed of *Montipora capitata*, *Montipora flabellata*, *Pocillopora* sp., and *Porites* sp. Coral stress was generally high, averaging 17.05% overall. The greatest amount of stressed hard coral was observed along the northeast backreef, where the *Boodlea* algal bloom was heavily concentrated and typically outcompeting the corals. Additionally, numerous pale/bleached colonies of *Pocillopora* and *Montipora* were observed along the majority of the forereef. Crown-of-thorns (COTs) predation was not thought to be a major contributing factor to coral stress.



Figures G.3.4.1. and G.3.4.2.--Hard coral and stressed coral cover.

Macroalgae cover averaged 27.98% overall and was highest within the lagoon (average 49.5%), where *Boodlea* was the dominant algae. An extensive bloom of *Boodlea* was noted during several surveys at Kure, most notably in the lagoon, along the eastern backreef and along the southwestern forereef, collectively forming a belt across the atoll. In certain areas, the bloom covered up to 90% of available substrate (not including sand) and formed a mat up to 0.5 m thick. Coralline algae was generally low, recording 6.32% cover (range 0–30%), with the highest amount of coverage along sections of the southern forereef.



Figures G.3.4.3. and G.3.4.4.--Macroalgae and coralline algae cover.

## G.4 Fish

### G.4.1 REA Fish Surveys

#### *Belt transect data*

During the survey period, 53 belt transect surveys were conducted at 22 sites around Kure Atoll. Jacks (Carangidae) were the largest contributor to total biomass with 22.82 kg 100 m<sup>-2</sup>. Chubs (Kyphosidae) were the second largest contributor to total biomass with 14.79 kg 100 m<sup>-2</sup>, followed by parrotfish (Scaridae) at 10.90 kg 100 m<sup>-2</sup> and surgeons (Acanthuridae) at 10.60 kg 100 m<sup>-2</sup>. (Table G.4.1.1.).

#### *Overall observations*

A total of 109 fish species were observed during the survey period by all divers. The average total fish biomass at the sites at Kure during the survey period was 24.82 kg 100 m<sup>-2</sup> for the belt transect surveys (Table G.4.1.2.).

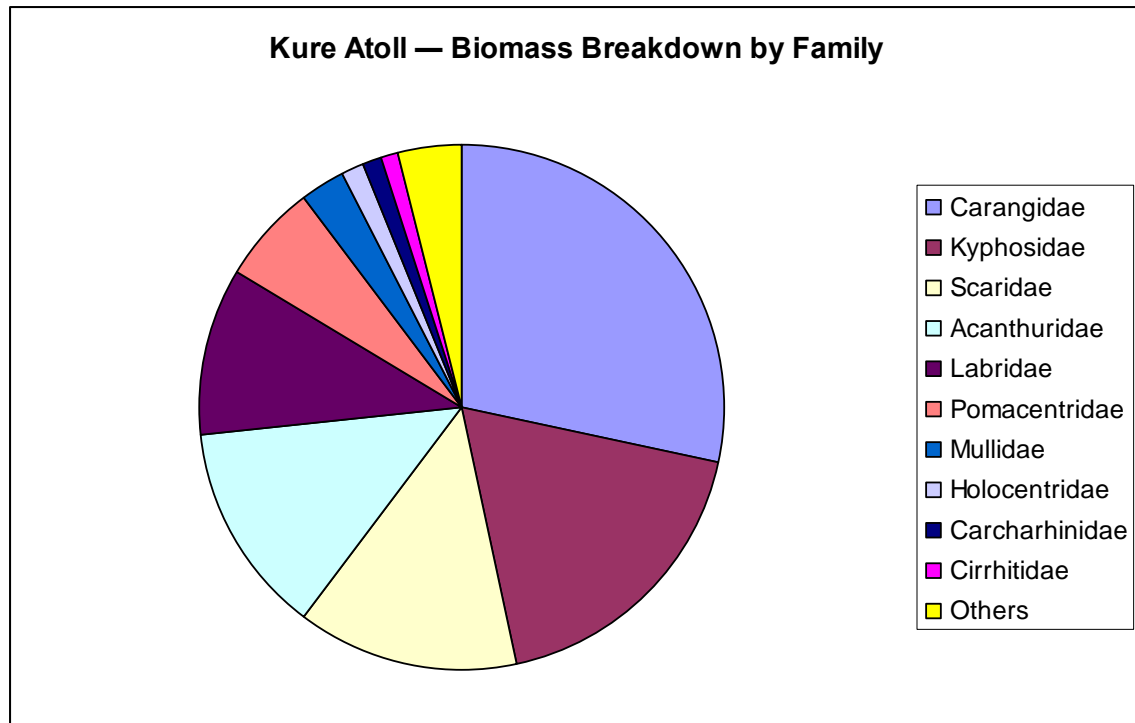


Figure G.4.1.1.--Total fish biomass composition by family.

Table G.4.1.2. --Coral reef fish biomass (kg 100 m <sup>-2</sup> ) by family at sites around Kure Atoll.													
Stratum – Depth	Site	Total	Acanth.	Carangid	Carchar.	Holocen.	Kyphosid	Labrid	Lutjanid	Mullid	Pomacen.	Scarid	Others
Backreef – Shallow	KUR-14	10.34	3.73				0.73	2.01		0.02	0.18	3.51	0.15
	KUR-141	6.87	2.42					1.08		0.12	0.34	2.87	0.04
	KUR-145	1.66	0.32					0.73			0.03	0.52	0.06
	KUR-17	9.63	4.80			0.48	0.50	1.86		0.06	0.22	1.51	0.19
	KUR-R36	8.41	1.86			0.07	0.30	2.27		0.09	0.64	2.88	0.30
Forereef – Deep	KUR-301	11.74	2.30				0.14	1.59	0.46	0.46	1.43	4.10	1.24
Forereef – Mid	KUR-02	4.13	0.96				0.10	0.84	0.16	0.01	1.00	0.57	0.50
	KUR-102	17.12	0.19			1.47	10.61	1.36	1.12	0.12	0.38	1.11	0.77
	KUR-103	14.05	1.03			4.04	1.93	2.22		0.68	1.06	1.92	1.16
	KUR-104	262.59	0.14	258.36		0.25		0.25	0.34	0.57	0.60	1.65	0.41
	KUR-105	5.26	1.88					2.17		0.13	0.43	0.37	0.28
	KUR-106	8.68	2.72					1.76		0.20	1.30	2.35	0.36
	KUR-12	7.15	0.81			1.52	0.24	0.90		0.19	0.48	2.40	0.61
	KUR-147	53.29	1.61			0.14	38.26	1.73	1.21	0.15	5.33	1.56	3.30
	KUR-148	14.45	6.93				0.58	1.83		0.02	2.50	1.75	0.84
	KUR-149	18.85	3.02		11.48			2.07		0.03	0.45	0.84	0.96
	KUR-379	15.43	4.36	4.44				1.76	0.78	0.06	1.74	2.04	0.25
	KUR-R33	17.50	0.82	2.58		0.95	8.01	0.78		0.51	0.33	2.29	1.23
Lagoon – Mid	KUR-18	7.92	0.99	0.71				1.82		1.32	1.33	1.54	0.21
Lagoon – Shallow	KUR-09	6.22	0.53			0.02		1.77		0.54	0.65	2.45	0.26
	KUR-154	41.24	6.54			0.73	28.09	1.80		0.16	0.67	1.80	1.45
	KUR-R35	3.42	0.83					1.58		0.32	0.30	0.05	0.35
Average		24.82	2.22	66.52	11.48	0.97	7.46	1.55	0.68	0.28	0.97	1.82	0.68

#### G.4.2 Towed-diver Fish Surveys

During the 2008 Reef Assessment and Monitoring Program (RAMP) mission, the Coral Reef Ecosystem Division (CRED) towboard team completed 14 surveys at Kure Atoll covering 32 km (32 ha) of ocean floor (Table G.4.2.1.). Mean survey length was 2.3 km with a maximum length of 2.7 km and a minimum of 1.8 km. Mean survey depth was 8.2 m with a maximum depth of 16.5 m and a minimum of 0.9 m in the backreef. Mean temperature on these surveys was 26.8 °C with a maximum temperature of 27.3 °C and a minimum of 25.5 °C.

Table G.4.2.1.--Survey statistics for towboard sampling during HI0809.

Island/Atoll/Reef	#	Length (km)					Depth (m)				Temperature (°C)			
		Sum	Mean	Max	Min	SD	Mean	Max	Min	SD	Mean	Max	Min	SD
Kure	14	32	2.3	2.7	1.8	0.02	8.2	16.5	0.9	5.9	26.8	27.3	25.5	0.4
Midway	16	39	2.4	3.2	1.9	0.03	9	16.9	0.7	5.9	27.2	28	26.9	0.3
Pearl & Hermes	27	63	2.3	3.1	1.3	0.03	10.3	16.3	1.2	5.2	27.3	27.9	26.8	0.3
Lisianski	12	24.7	2.1	2.3	1.7	0.02	10	14.2	1.6	3.9	28	28.2	27.8	0.1
Laysan	5	11.5	2.3	2.5	2.1	0.01	11.8	13.6	9.2	1.5	27.9	28	27.8	0.1
Maro Reef	11	23.4	2.1	2.4	1.7	0.01	13.3	16.5	9.5	1.8	28.2	28.4	27.9	0.1
French Frigate	26	56.5	2.2	2.9	1.4	0.03	11.5	17.1	1.8	4.5	27.6	28.3	26.9	0.2

One hundred seventy-two individual large-bodied reef fish (> 50 cm TL) of 15 different species were encountered at Kure Atoll (Table G.4.2.2.). Overall numeric density for this class of reef fishes was 0.05 kg/100 m<sup>2</sup> (5.361 #/ha) with a biomass density of 0.28 kg/100 m<sup>2</sup> (0.028 t/ha). Numeric and biomass densities were dominated by *Chlorurus perspicillatus*. Overall, Scarids contributed 36% of the overall numeric density with Carangids contributing 25% (Fig. G.4.2.1.). Both of these families dominated biomass densities as well with Carangids contributing 43% of the total biomass and Scarids contributing 18% (Fig. G.4.2.2.).

Numeric and biomass densities for large-bodied reef fish were higher on the forereef compared to the backreef (Fig. G.4.2.3.). Biomass was evenly distributed around the atoll with high levels of *Aetobatus narinari* and *Pseudocaranx dentex* along the eastern forereef, *Caranx ignobilis* in the south, and *Seriola dumerili* in the west. As many of these are large-bodied species, these high biomass levels are often the result of a small number of individuals.

Table G.4.2.2.--Species numeric and biomass density for large-bodied reef fish (> 50 cm TL) observed at Kure Atoll during 2008 CRED towed-diver surveys.

Species	#	#/100m2	#/ha	Biomass (kg)	kg/100m2	t/ha
Aetobatus_narinari	4	0.00125	0.12468	152.78392	0.04762	0.00476
Aprion_virescens	13	0.00405	0.40521	67.51224	0.02104	0.00210
Caranx_ignobilis	5	0.00156	0.15585	146.84056	0.04577	0.00458
Caranx_melampygus	8	0.00249	0.24936	29.09648	0.00907	0.00091
Chlorurus_perspicillatus	63	0.01964	1.96372	160.65000	0.05007	0.00501
Coris_flavovittata	4	0.00125	0.12468	17.60000	0.00549	0.00055
Enchelycore_pardalis	1	0.00031	0.03117	8.41629	0.00262	0.00026
Epinephelus_quernus	2	0.00062	0.06234	6.17210	0.00192	0.00019
Fistularia_commersonii	1	0.00031	0.03117	0.07541	0.00002	0.00000
Myrichthys_magnificus	1	0.00031	0.03117	0.25000	0.00008	0.00001
Naso_unicornis	18	0.00561	0.56106	46.21453	0.01441	0.00144
Oplegnathus_punctatus	20	0.00623	0.62340	53.43721	0.01666	0.00167
Parupeneus_cyclostomus	1	0.00031	0.03117	1.55000	0.00048	0.00005
Pseudocaranx_dentex	26	0.00810	0.81042	95.42267	0.02974	0.00297
Seriola_dumerili	5	0.00156	0.15585	128.22850	0.03997	0.00400
Grand Total	172	0.05361	5.36126	914.24991	0.28497	0.02850

Numeric Density Contribution by Family for Large-Bodied Reef Fish (>50cmTL) observed at Kure Island During 2008 CRED Towed-Diver Surveys

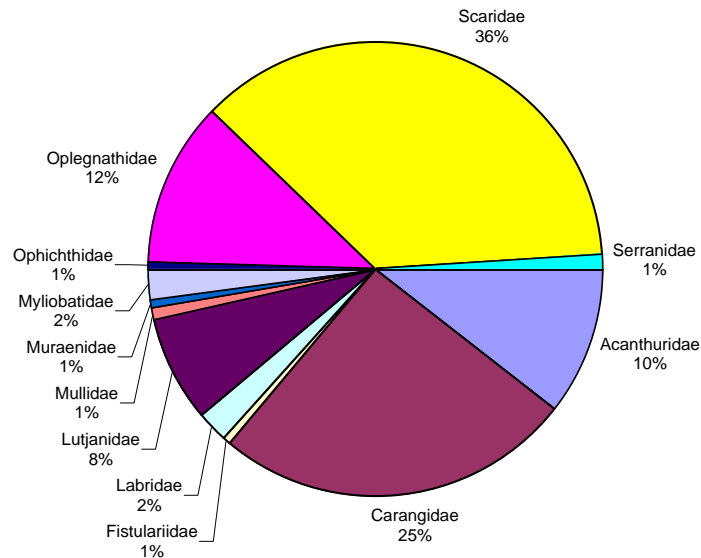


Figure G.4.2.1.--Numeric density by family.

**Biomass Density Contribution by Family for Large-Bodied Reef Fish (>50cmTL)  
observed at Kure Island During 2008 CRED Towed-Diver Surveys**

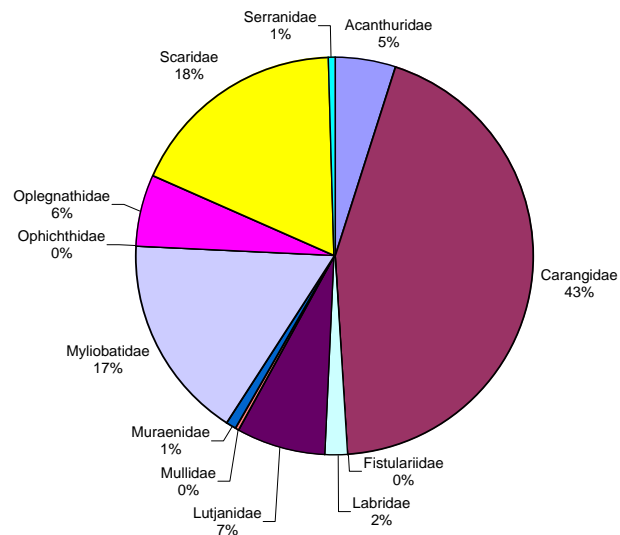


Figure G.4.2.2.--Biomass density by family.

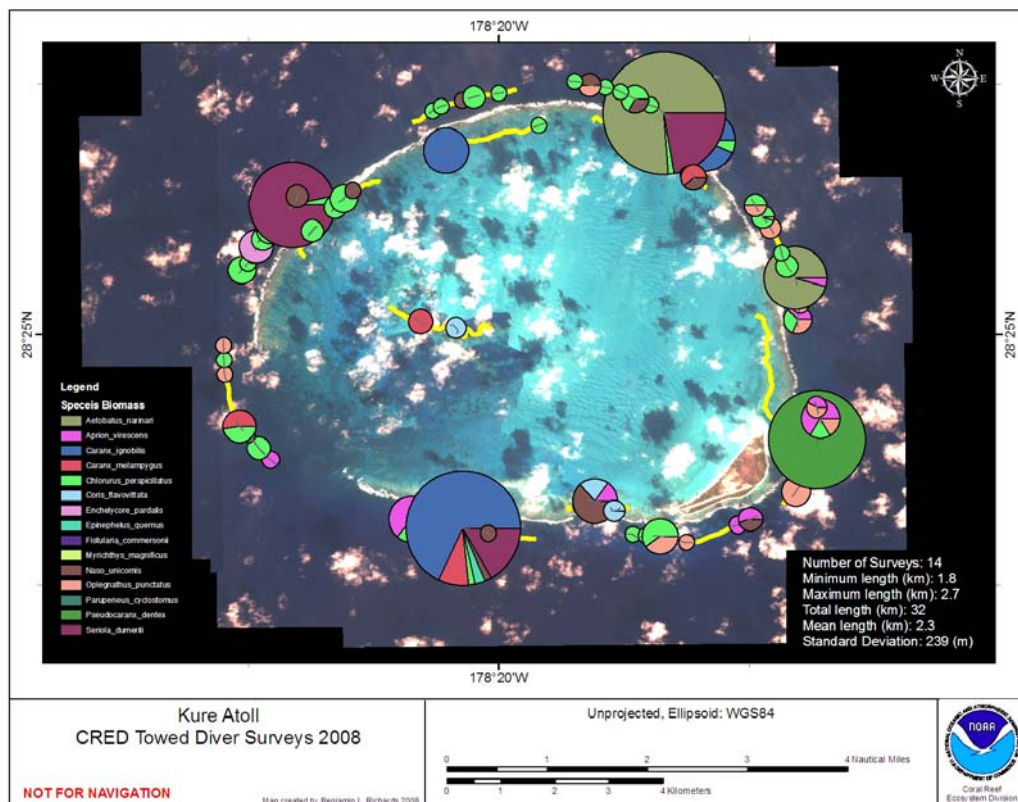


Figure G.4.2.3.--Geographic distribution of biomass around Kure Atoll. Each species is represented by a legend color. Diameter of pie chart is proportional to total biomass of all species encountered on the underlying survey.

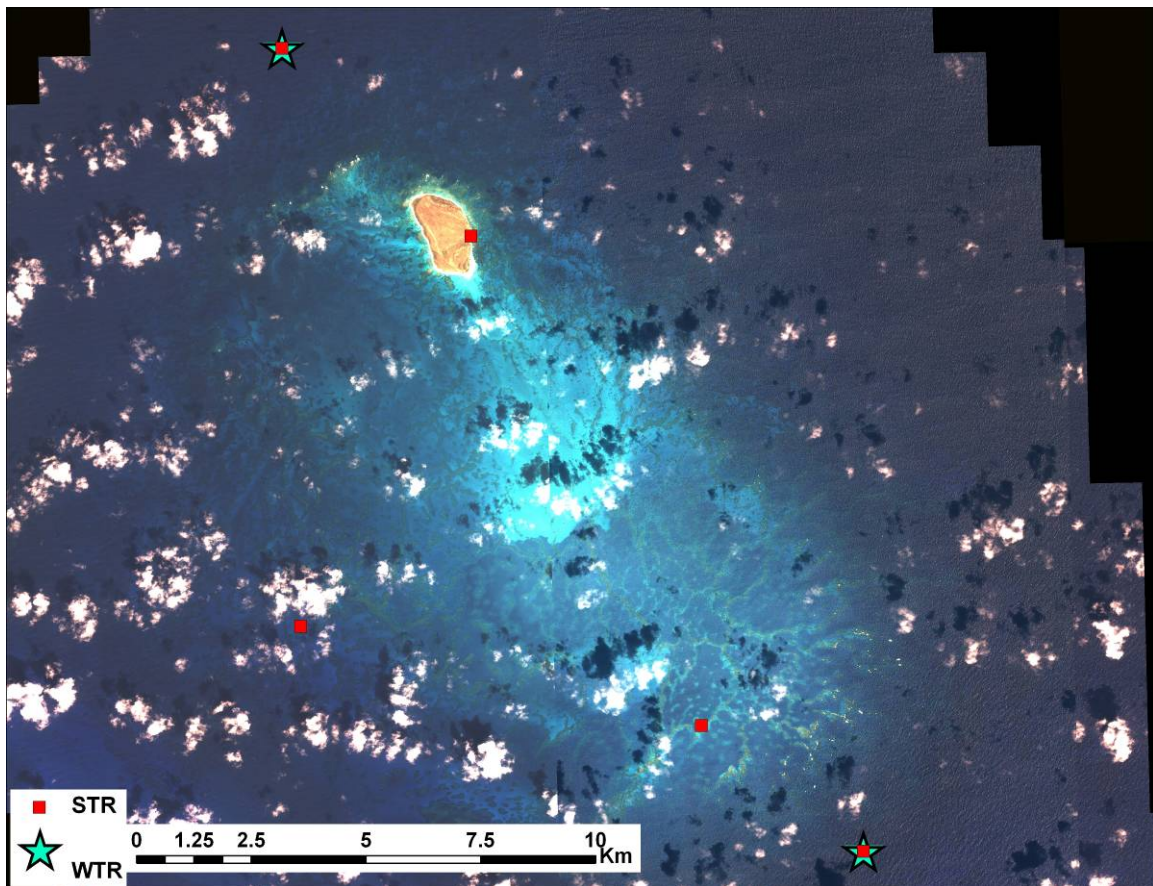


## Appendix H: Lisianski Island

### H.1. Oceanography and Water Quality

#### Moorings (Fig. H.1.1., Table H.1.1.)

At Lisianski Island during HI0809, five subsurface temperature recorders (STRs) were recovered and replaced. One sea surface temperature (SST) buoy and anchor was installed in place of one that was lost. Two Wave and Tide Recorders (WTRs) were removed and replaced, one from the southeast corner and one from the northwest side of the island. New mooring deployments at Lisianski included one new ecological acoustic recorder (EAR) site on the northwest next to the WTR location. Due to instrumentation problems, the northern, WTR (a Seabird 26plus) from Lisianski was removed, downloaded, cleaned, and the same instrument was returned to its mooring. This was done due to the limited battery life of the Seabird 26 that was brought to replace this instrument. By replacing the same instrument at Lisianski, the data set will be complete, although the risk of failure is higher due to the instrument having not been calibrated. The data from this instrument was verified and processed before re-deployment and appears to be working correctly.



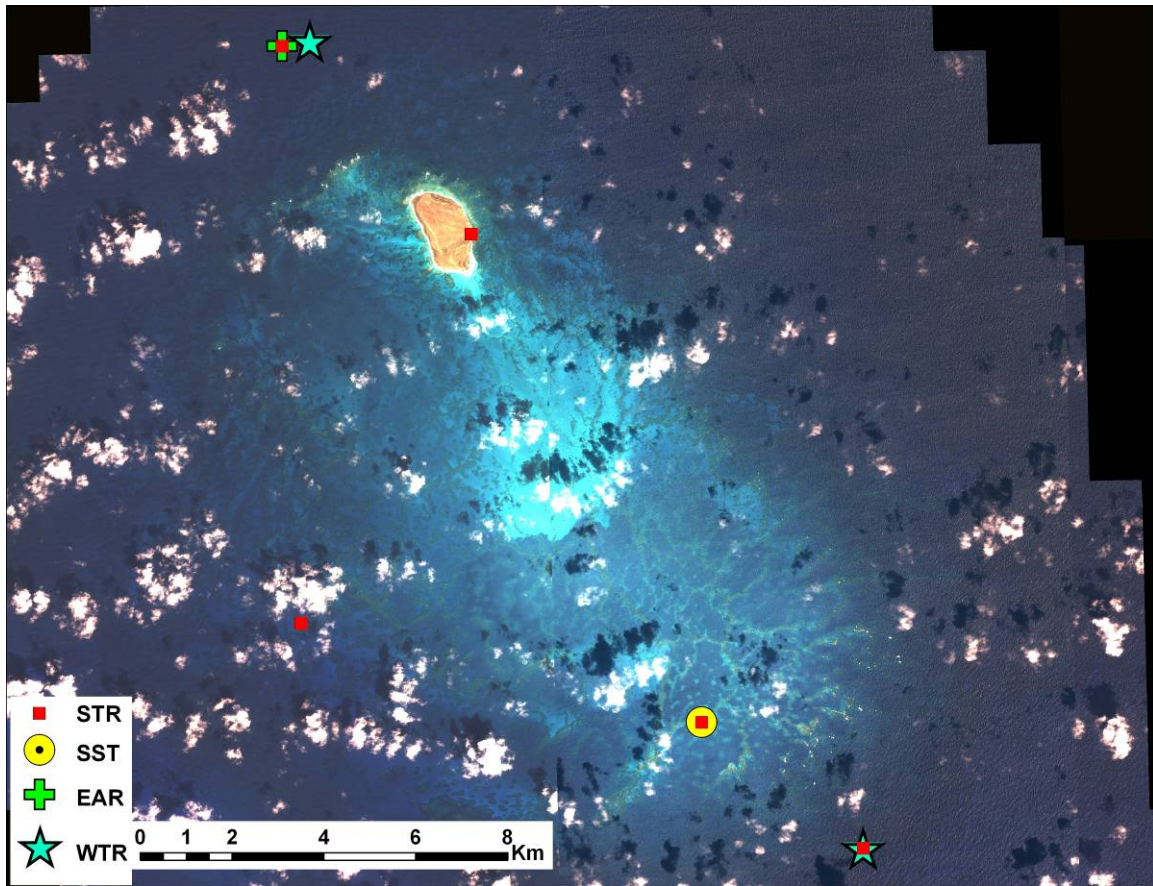


Figure H.1.1.--Moored oceanographic instrumentation map for Lisianski Island. Instruments recovered (top) and instruments deployed (bottom).

Table H.1.1.--Moored oceanographic instrumentation table for Lisianski Island.

Instrument	Work	Serial Number	Latitude	Longitude	Data End	Depth
STR	Retrieval	3920707-0166	27.78486	-175.83974	02-OCT-08	22.86
EAR	Deployment	9300394 85	26.10010	-173.99799	04-OCT-08	22.56
STR	Deployment	3939038-3008	26.10010	-173.99799	04-OCT-08	22.56
WTR	Retrieval	26P36859-1031	26.10010	-173.99799	04-OCT-08	23.77
STR	Retrieval	3943236-3079	26.10010	-173.99799	04-OCT-08	23.77
STR	Deployment	3939038-1818	25.96762	-173.91583	04-OCT-08	10.36
SST	Deployment	10018170	25.96762	-173.91583	04-OCT-08	10.36
STR	Retrieval	3939179-1189	25.96762	-173.91583	04-OCT-08	10.36
SST	Lost		25.96762	-173.91583	04-OCT-08	10.36
STR	Deployment	3951023-4493	25.94299	-173.88414	04-OCT-08	21.34
WTR	Deployment	2632718-0378	25.94299	-173.88414	04-OCT-08	21.34
STR	Retrieval	3943236-3073	25.94299	-173.88414	04-OCT-08	21.34
WTR	Retrieval	2632718-0359	25.94299	-173.88414	04-OCT-08	21.34
STR	Deployment	3939038-1869	25.98702	-173.99434	05-OCT-08	14.63
STR	Retrieval	3943236-3068	25.98702	-173.99434	05-OCT-08	14.63
WTR	Deployment	26P36859-1031	26.10019	-173.99795	05-OCT-08	23.77
STR	Deployment	3939038-3023	26.06333	-173.96099	05-OCT-08	0.91
STR	Retrieval	3933179-1199	26.06333	-173.96099	05-OCT-08	0.91
STR	Retrieval	3920707-0166	27.78486	-175.83974	02-OCT-08	22.86

## Preliminary Mooring Results

The five STRs, and two WTRs recovered from Lisianski yielded usable data sets (Fig. H.1.2.). Between September 2006 and September 2008, subsurface water temperatures around Lisianski fluctuated with seasonal variability typical for these latitudes; lows occurring between January and March ( $\sim 18^{\circ}\text{C}$ ) and highs between August and October ( $\sim 28^{\circ}\text{C}$ ). Shallower instruments showed larger diurnal fluctuations than those in deeper waters due to daily solar heating and cooling (Fig. H.1.2.). Significant wave height throughout the year at Lisianski was dominated by the northerly swells that peak through the boreal winter months of December–February. Southern shores saw significantly less energy, surpassing northern values only during smaller summer swells. These wave conditions are typical for this region (Fig. H.1.3.).

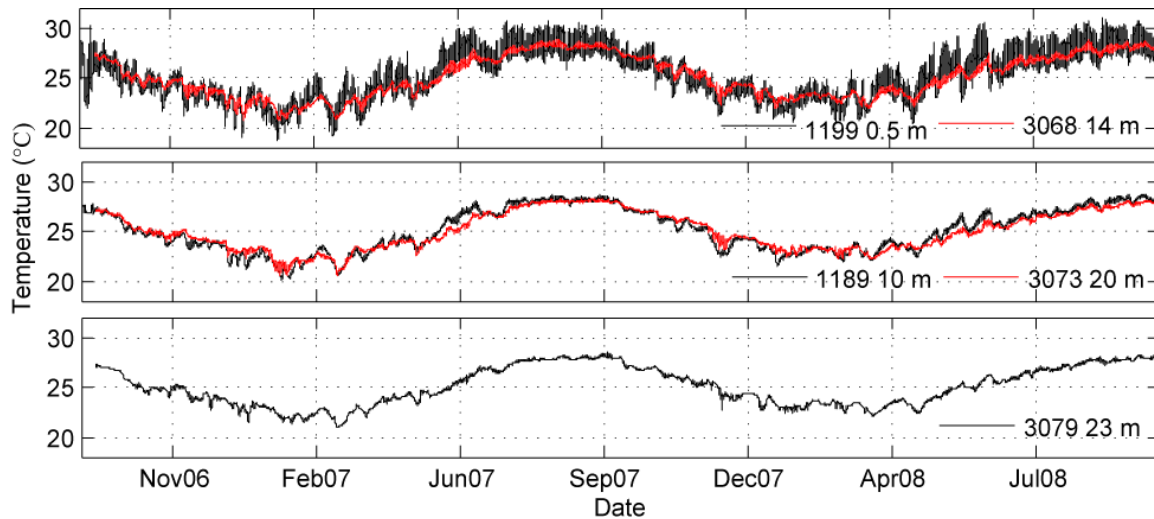


Figure H.1.2.--Temperature and salinity data obtained from four STRs around Lisianski Island.

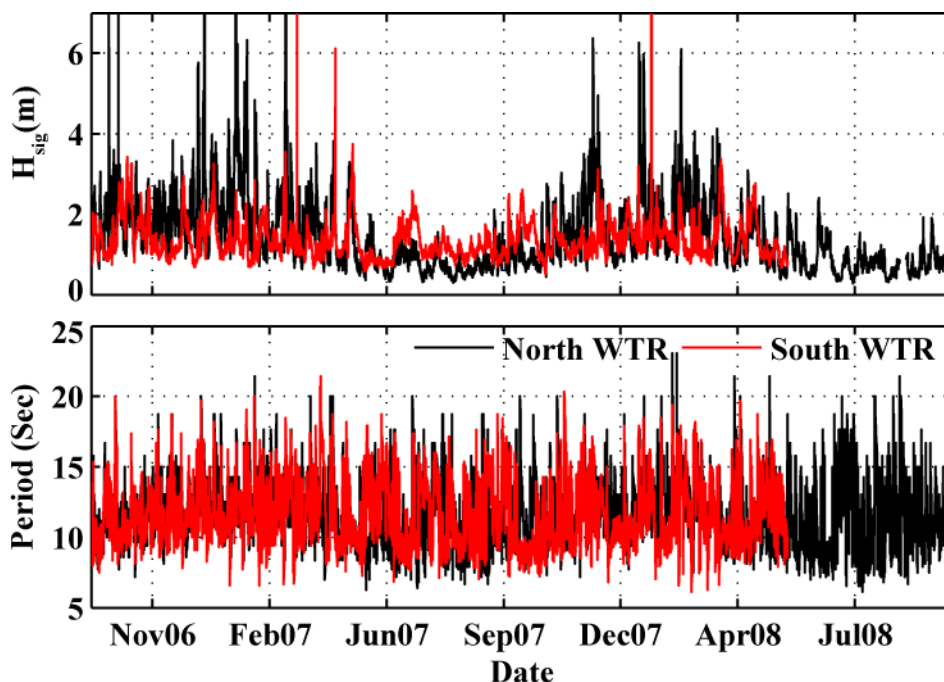


Figure H.1.3.--Significant wave height from the southern WTR.

### Water Quality:

Nineteen shallow-water conductivity, temperature and depth (CTD) casts were conducted at the 30 m bathymetric contour around Lisianski Island at approximately 2-nautical mile (nmi) intervals using a Seabird 19+ with additional dissolved oxygen (DO) and transmissometer sensors attached (Fig. H.1.4.). All of the shallow-water CTD casts on the outside of the atoll were conducted on October 5, 2008. Eighteen discrete water samples (including two duplicates), collected concurrently with shallow-water CTD casts, were taken at four of the shallow water CTD sites using a daisy chain of Niskin bottles at 1 m, 10 m, 20 m and 30 m depth bins. Nutrient and chlorophyll samples were processed and stored according to protocol and will be sent out for analysis following the cruise.



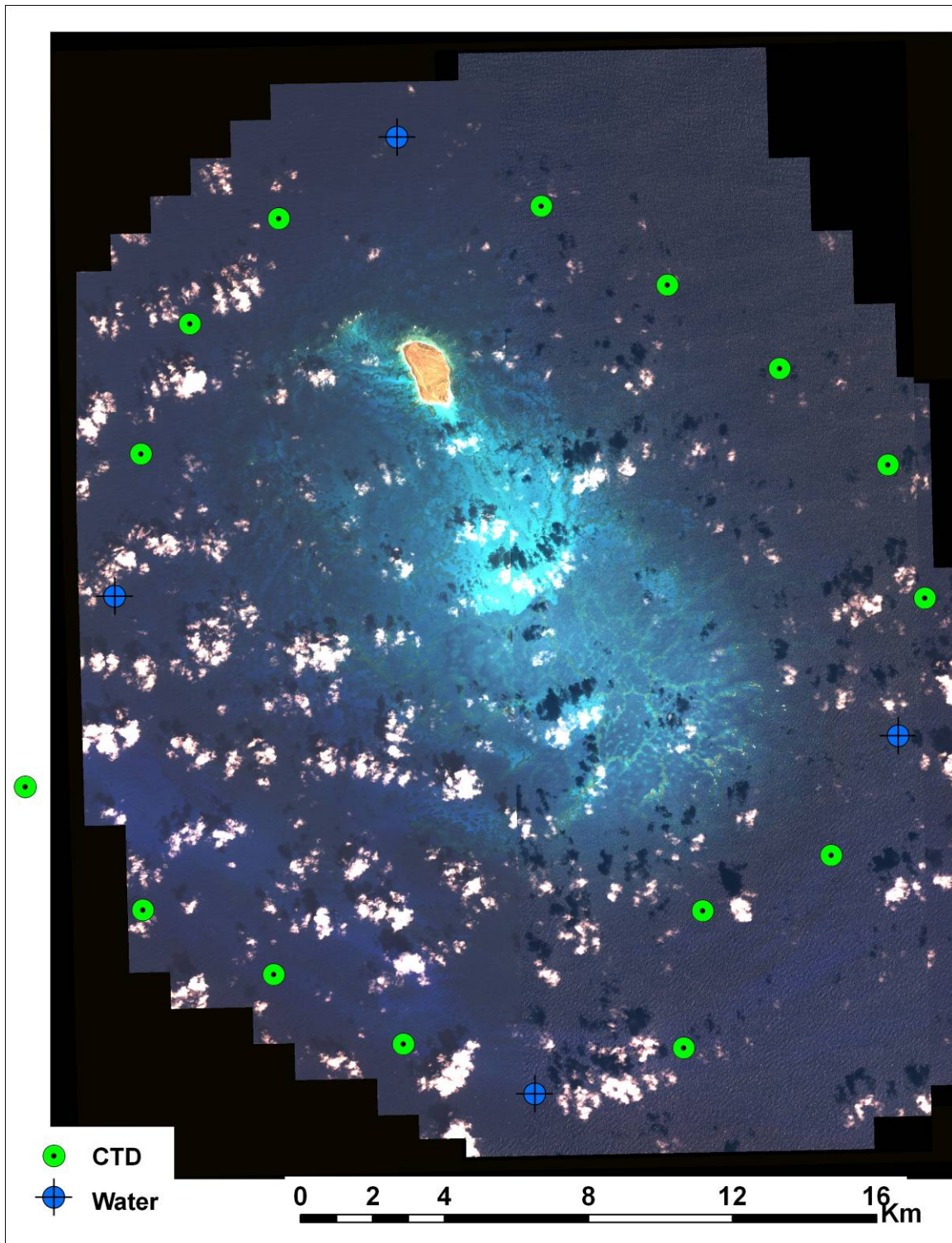


Figure H.1.4.--Shallow-water CTD and water sampling locations around Lisianski Island.

One permanent shipboard CTD site near Lisianski Island was sampled (Fig. H.1.5.). This cast included a CTD profile to 500 m deep, water samples that will be analyzed for chlorophyll and nutrients at the 3 m, 80 m, 100 m, 125 m and 150 m bins and water samples that will be analyzed for carbonate chemistry (DIC and  $A_T$ ) at the 3 m and 125 m

depth bins. The water samples were processed and stored according to protocol and will be sent out for analysis following the cruise.

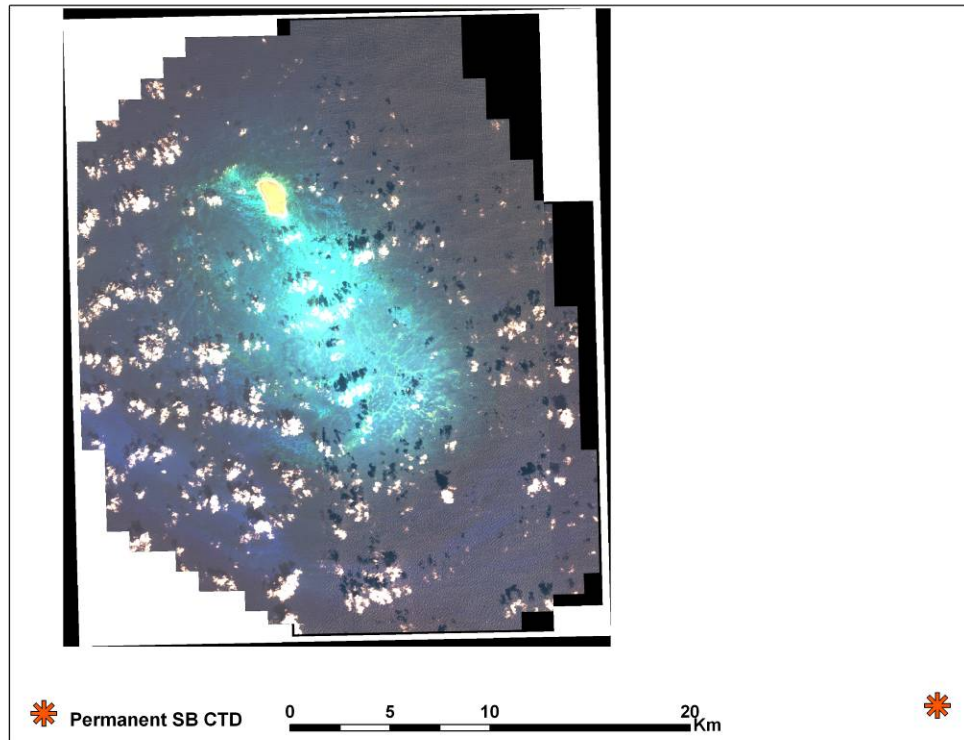


Figure H.1.5.--Permanent shipboard CTD location near Lisianski Island.

## H.2. Rapid Ecological Assessment (REA) Site Descriptions

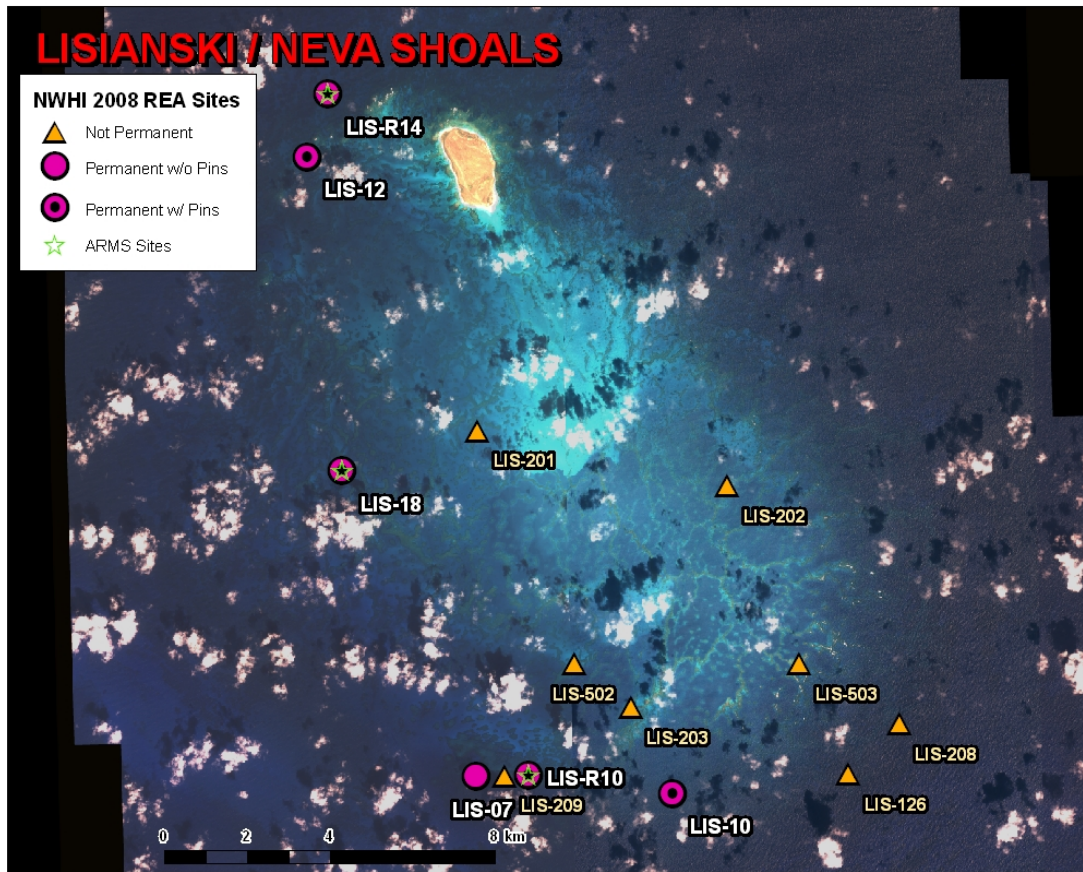


Figure H.2.1.--REA visited at Lisianski Island during HI-08-09.

Table H.2.1.--REA sites visited at Lisianski Island during HI-08-09 (see also Table A.2.2).

LIS-R7	Forereef	9.7–14.0	25°57.237 N	173°58.228 W	5 Oct 2008
LIS-10	Forereef	8.5–11.3	25°56.460 N	173°55.344 W	5 Oct 2008
LIS-R10	Forereef	10.0–14.6	25°56.671 N	173°57.210 W	5 Oct 2008
LIS-12	Forereef	7.0–8.2	26°03.954 N	174°00.102 W	4 Oct 2008
LIS-R14	Forereef	13.0–14.9	26°04.702 N	173°59.821 W	4 Oct 2008
LIS-18	Forereef	6.4–8.8	26°00.257 N	173°59.642 W	4 Oct 2008
LIS-503	Forereef	2	25°57.973 N	173°53.679 W	5 Oct 2008
LIS-126	Forereef	16	25°56.671 N	173°53.039 W	5 Oct 2008
LIS-209	Forereef	7	25°56.650 N	173°51.521 W	5 Oct 2008
LIS-203	Forereef	4	25°57.456 N	173°55.877 W	5 Oct 2008
LIS-208	Forereef	15	25°57.266 N	173°52.377 W	5 Oct 2008
LIS-202	Forereef	4	26°00.065 N	173°54.624 W	5 Oct 2008
LIS-201	Forereef	4	26°00.713 N	173°57.879 W	5 Oct 2008
LIS-502	Forereef	4	25°57.968 N	173°56.614 W	5 Oct 2008



#### LIS-R14

04 October 2008

W-NW, bank reef; depth range: 13-14.9 m. Visibility ~ 12 m. This forereef system was dominated by coral but contained a high degree of algal diversity. The algal community was dominated by crustose coralline red algae and moderately epiphytized *Halimeda opuntia* and *H. velasquezii*. *Lobophora variegata*, turf algae, non-geniculate branched coralline red algae, and *Microdictyon setchellianum* were also documented during the LPI survey. *Halimeda discoidea*, *Caulerpa racemosa*, cyanophytes, and species of *Peyssonnelia*, *Jania*, *Neomeris*, and *Neostoma* were documented during the Roving Diver survey. Moderately high percent live coral cover (45%) was observed. Fissioned colonies of *Porites lobata* and large mounds of *P. evermanni* dominated this site. Several colonies of *Montipora capitata* were present while colonies of *Pavona duerdeni* were rare, but appeared to exhibit significant compromised health states. There was low abundance of macroinvertebrates with the exception of the boring urchins *Echinostrephus aciculatus* and *Echinometra mathaei*. The invasive hydroid, *Pennaria disticha*, was prevalent on the transect stakes. Moderate diversity and abundance of fishes were found at this site. Three species of fish were commonly seen: *Chlorurus perspicillatus*, *Ctenochaetus strigosus* and *Thalassoma duperrey*. While most of the smaller fishes were found in the transect, off transect recordings of large fishes included four *Aprion virescens* and one large *Monotaxis grandoculis*.

#### LIS-12

04 October 2008

W-NW, spur-and-groove system on bank reef; depth range: 7-8.5 m. Visibility ~ 15 m. This site was highly dominated by non-geniculate branched and crustose coralline red algae, as well as highly epiphytized *Halimeda opuntia*. *H. velasquezii*, *Lobophora variegata*, *Dictyosphaeria versluysii*, *D. cavernosa*, turf algae, and a species of *Peyssonnelia* were also documented on the LPI survey. *Peyssonnelia* and non-geniculate coralline red algae form large, elaborate structures at this site. Species of *Haloplegma* and *Chrysomenia*, and *Caulerpa taxifolia* were documented during the Roving Diver survey. Coral cover was low (5.2%) and was composed mostly of *Porites lobata* and *P. evermanni*. Several cases of mild, focal bleaching were observed in both species. There was low abundance of macroinvertebrates with the exception of the boring urchins, *Echinostrephus aciculatus* and *Echinometra mathaei*. The invasive hydroid, *Pennaria disticha*, was prevalent on the transect stakes. The brittle star, *Ophiocoma pica*, was abundant within non-geniculate coralline red algae clumps and *Peyssonnelia*. This site contained low to moderate abundances and diversity of fish. While species diversity was low at the first two transects, diversity at the third transect increased. The most common fish encountered on transect included *Thalassoma duperrey*, *Stegastes fasciolatus* and *Chlorurus perspicillatus*. Off transect sightings included three *Aprion virescens* and one large *Caranx ignobilis*, as well as large schools of *Naso lituratus* and *N. brevirostris*.



#### LIS-18

04 October 2008

W; bank reef; moderate topographical relief, depth range: 6.5–8.8 m. Visibility ~ 10 m. This site was characterized by carbonate/sand with moderate coral and algae cover. Benthos was dominated by highly epiphytized *Microdictyon setchellianum*, *Halimeda opuntia*, and non-geniculate branched coralline red algae along with a high percent cover of turf algae. Cyanobacteria was found colonizing a large percentage of the macroalgae. One species of *Martensia*, *Lobophora variegata*, *Dictyosphaeria versluysii*, *Halimeda velasquezii*, *Laurencia galtsoffii* and crustose coralline red algae were also documented during the LPI survey. *Dictyosphaeria cavernosa*, *Dictyota ceylanica* and a species of *Peyssonnelia* were documented during the Roving Diver survey. Coral cover was 18% and was composed mostly of *Porites lobata* and *P. evermanni*. Several cases of mild bleaching and trematodiasis were observed in both species. Macroinvertebrate abundance was low with the exception of the boring urchins, *Echinostrephus aciculatus* and *Echinometra mathaei*. The invasive hydroid, *Pennaria disticha*, was prevalent on the transect stakes. The brittle star, *Ophiocoma pica*, was abundant within non-geniculate coralline red algae clumps and *Peyssonnelia*. Overall fish abundance and diversity were moderate for this site. This site was dominated by the surgeonfishes, *Acanthurus nigroris* and *A. olivaceus* and the wrasse, *Thalassoma duperrey*. Large schools of *A. nigroris* and *A. olivaceus* were seen off transect as well, along with three *Aprion virescens* and a couple of large *Naso unicornis*. One large ulua visited for most of the dive but was initially recorded on transect. No other large off transect sightings occurred.

#### LIS-R10

05 October 2008

W-SW; bank reef, moderately high topographical relief bank reef; depth range: 10–15 m. Visibility ~ 15 m. This spur-and-groove forereef site exhibited moderately high percent coral cover (50.8%). *Porites evermanni* (42.8%) and *Montipora patula* (27.6%) were the dominant species found. Bleaching was observed in most *M. capitata* colonies. This site had a low overall percent macroalgae cover. The algal community was dominated by crustose coralline red algae, *Lobophora variegata*, and turf algae with small individuals of *Halimeda velasquezii* and *H. opuntia*. A species of *Peyssonnelia* was also documented during the LPI survey. *Dictyosphaeria cavernosa*, a species of *Neomeris*, a species of *Amphiroa*, *Chondrophycus parvipapillata*, and a cyanophyte were documented during the Roving Diver survey. Virtually no macroinvertebrates were observed at this site. Only two *Echinometra* and one *Coralliphilia* sp. were recorded. Fish abundance and diversity were moderate to high at this site. Parrotfishes (*Chlorurus perspicillatus*, *C. sordidus* and *Scarus dubius*) and the surgeonfish *Ctenochaetus strigosus* were the most abundant fish observed. Large coral ledges housed groups of squirrelfish and soldierfish. Large fish abounded, with 3 large *Aprion virescens*, 13+ *Caranx ignobilis*, 2 *C. melampygus* and a grey reef shark observed off transect.

#### LIS-10

05 October 2008

W-SW; southeast bank reef, moderate topographical relief; depth range: 8.5–11.3 m. Visibility ~ 10 m. Spur-and-groove system. High percent live coral cover (51.6%) was

observed with *Porites compressa* (51.7%) and *P. evermanni* (27.2%) being the dominant species. Several cases of bleaching were observed in colonies of *Montipora capitata*, *M. patula* and *P. compressa*. This site had a low overall percent of macroalgae cover. The algal community was dominated by crustose coralline red algae, *Lobophora variegata*, and turf algae colonized with cyanophytes. *Dictyosphaeria versluysii* was also documented during the LPI survey. A species of *Neomeris*, *Halimeda velasquezii*, *Microdictyon setchellianum*, non-geniculate branched coralline red algae, *Dasya iridescentis*, and *Caulerpella ambigua* were documented during the Roving Diver survey. Virtually no macroinvertebrates were observed at this site. Only five *Echinometra* were recorded. The invasive hydroid, *Pennaria disticha*, was prevalent on the transect stakes. This site contained moderate abundance and diversity of fishes. Juvenile parrotfishes *Chlorurus perspicillatus*, *C. sordidus* and *Scarus dubius* dominated the site, as well as *Ctenochaetus strigosus* and *Stegastes fasciolatus*. A small group of adult *Caranx ignobilis* visited the divers throughout the survey, as well as two *C. melampygus*.

#### LIS-R7

05 October 2008

W-SW; bank reef; moderately high topographical relief depth range: 9.7–14.3 m. Visibility ~ 25 m. Coral dominated the benthos at this site with a moderate percent cover of turf algae, crustose coralline red algae, *Dictyosphaeria cavernosa*, and highly epiphytized *Halimeda opuntia*. Small individuals of *Halimeda velasquezii*, *Caulerpella ambigua*, *Microdictyon setchellianum* and a gelid were documented during the LPI survey. A species of *Amphiroa*, a species of *Peyssonnelia*, a cyanophyte, and non-geniculate branched coralline red algae were documented during the Roving Diver survey. This forereef site was characterized by high coral cover (59.2%). Members of the *Porites* genus dominated the reef with *P. evermanni* (35.2%), *P. compressa* (28.9%), and *P. lobata* (18.5%) being most abundant. Bleaching and other compromised health states were observed. Virtually no macroinvertebrates were observed at this site. Only two *Echinometra* and one *Calcinus* sp. were recorded. The invasive hydroid, *Pennaria disticha*, was prevalent on the transect stakes. This site contained moderate diversity but low to moderate abundances of fish. *Stegastes fasciolatus* dominated this site and was the only species of uniform abundance. Groups of large *Chromis hanui* were seen both on and off transect, and *Pseudocheilinus* species (*P. evanidus* and *P. octotaenia*) were more common than at other sites. Approximately 16 large *Caranx ignobilis* circled divers for the length of the dive.

LIS-203 10/5/08

N 25° 57.456 W 173° 55.877

Depth: 4.6 m

This site was located on the southern forereef of Neva Shoals. It was established by the REA fish team as a new sampling location in the shallow forereef stratum. The area was a shallow shoal with moderate relief, however, the substrate was dominated by algae and there was no live coral cover. The rolling mounds were completely covered by algae that appeared to be a *Dictyosphaeria* spp. The site was dominated by small fishes, wrasses, scarids, and acanthurids. Both transects had low species diversity. Off transect, over sand patches, there were schools of Acanthurids: 20 *Acanthurus nigroris* at 20 cm, 30 A.

*triestegus* at 15 cm, 20 *Acanthurus olivaceus* at 20 cm, and a few large *Naso unicornis* at 40 cm. There was also a large *Caranx ignobilis* at 120 cm off transect.

LIS-209        10/5/08  
N 25° 56.650 W 173° 51.521  
Depth: 7.3 m

This site was located on the southern forereef of Neva Shoals. It was established by the REA fish team as a new sampling location in the moderate forereef stratum. The habitat was rolling spurs with shallow grooves, and both spurs and grooves had 100% live coral cover. The dominant corals were *Porites compressa*, *P. lobata* in the mound form, *Montipora flabellata*, and *M. capitata*. Transect B was almost 100% *P. compressa*, with a few *P. lobata* mounds. Relief and complexity were high at this site. The transects had low fish species diversity, and were dominated by *Thalassoma duperrey* and *Stegastes fasilatus*. Off transect there was a *Tranodon obesus* at 100 cm, a *Bodianus bilunulatus* at 40 cm, and large schools of *Melichthys niger* and *Abudefduf abdominalis* in the water column.

LIS-502    10/5/08  
N 25° 57.968 W 173° 56.614  
Depth: 4 m

This site is located in the southern forereef of Neva Shoals. It was established by the REA fish team as a new sampling location in the shallow forereef stratum. Coral cover here was low (~ 3%), with sparse patches of *Porites lobata*, rubble, sand, and small amounts of turf algae, *Halimeda*, and red calcareous algae. Complexity was moderate, with narrow sand channels and small rocky outcroppings. Fish diversity and abundances were very low, although a large *Caranx ignobilis* sent the biomass skyrocketing. Just off transect a fair number of small and large fish congregated, and a whitetip reef shark made an appearance.

LIS-503    10/5/08  
N 25° 57.973 W 173° 53.679  
Depth: 2 m

This site is located in the southeastern forereef of Neva Shoals. It was established by the REA fish team as a new sampling location in the shallow forereef stratum. The first half of the first transect had very low coral cover (~ 8%) comprised of *Porites lobata*, *P. meandrina*, and *P. damicornis*. Turf algae, red calcareous algae, and *Halimeda* contributed to the algae assemblage. The remainder of the transects had very high coral cover, with a Zoanthid species dominating at almost 70%. Fish diversity and abundances were very low, with the wrasses, *Thalassoma duperrey* and *Stethojulis balteata* being most common.

LIS-201        10/5/08  
N26° 00.713 W-173° 57.879  
Depth: 4 m

This site is located approximately 3 miles south of Lisianski Island. It was established by the REA fish team as a new sampling location in the shallow forereef stratum. Water

clarity was very poor, with visibility being approximately 15 feet. The substrate was almost completely void of live coral, composed of fairly level rubble with a few larger outcroppings located randomly about. Fish abundance and diversity were very low at this site, with only eight species identified on transect. A school of 7 *Caranx melampygus* all approximately 45 cm were the largest fish recorded, while a school of 15 juvenile scarids in the 5 cm range were the most abundant species. Other fish recorded include *Thalassoma duperrey*, *Canthigaster jactator*, and *Oxycheilinus bimaculatus*.

LIS-202        10/5/08  
N26°00.065 W-173°54.624  
Depth: 4 m

This site was located on the west end of Neva Shoals. It was established by the REA fish team as a new sampling location in the shallow forereef stratum. Visibility was very poor at this site, at approximately 20 feet. The substrate was almost completely void of live coral, composed of fairly level rubble with a few larger outcroppings along the transect. Fish abundance and diversity were very low at this site, the most abundant species being juvenile scarids less than 7 cm. Other species recorded, though not in abundance, include *Canthigaster jactator*, *Coris venusta*, *Thalassoma duperrey*, and *Stegastes balteata*. Large sand patches also surrounded the survey site.

LIS-208        10/5/08  
N25°57.266 W-173°52.377  
Depth: 15 m

This site is located on the southeast forereef of Neva Shoals. It was established by the REA fish team as a new sampling location in the moderate forereef stratum. Visibility was good at approximately 80 feet, and current was minimal. Coral cover was nearly 100 percent and was composed of various species such as *Porites lobata*, *P. evermanni*, *P. compressa*, *Montipora capitata*, *M. flabellata*, and *Fungia scutaria*. Fish diversity and abundance, however, were low with less than a dozen species recorded on transect. A school of 15 *Caranx ignobilis* ranging from 60 to 75 cm were not only the largest fish in the area, but also the most abundant. The most abundant species under 20 cm were *Thalassoma duperrey* and *Stegastes fasciolatus*. Two *C. melampygus* and one *Aprion virescens* were also seen off transect.

LIS-126        10/5/08  
N25°56.671 W-173°53.039  
Depth: 16 m

This site is located on the southeast forereef of Neva Shoals. It was established by the REA fish team as a new sampling location in the moderate forereef stratum. Visibility was good at approximately 80 feet, and current was minimal. Coral cover was nearly 100 percent and was composed of various species such as *Porites lobata*, *P. evermanni*, *P. compressa*, *Montipora capitata*, *M. flabellata*, and *Fungia scutaria*. Fish diversity was moderate, but abundance was relatively low. One 60-cm *Caranx ignobilis* was recorded on transect, being the largest fish recorded, and eight *Stegastes fasciolatus* being the most abundant species. Several larger species were seen off transect to include one 40-cm *Caranx melampygus*, one 55-cm *Aprion virescens*, and one 150-cm *Triaenodon obesus*.

### H.3. Benthic Environment

#### H.3.1. Algae

Benthic communities around Lisianski Atoll were dominated by macroalgal and coral functional groups (Table H.3.1.1.). There was a higher percent cover of macroalgae than turf algae at four of the six sites surveyed. Also, coral percent cover exceeded that of macroalgae at four of the six sites (Table H.3.1.1.). A combined total of 20 species of macroalgae were observed (9 chlorophytes, 2 ochrophytes, 9 rhodophytes) from the 6 sites surveyed (Tables H.3.1.2., H.3.1.3.). *Halimeda opuntia* was the most prevalent species encountered and covered 2.4% to 24% of the substrate at five of the six sites (Table H.3.1.3.). Plants often formed dense patches and were generally moderately colonized with epiphytes. *Halimeda velasquezii* was documented at all of the sites surveyed and comprised 0.8% to 10% of the substrate (Table H.3.1.3.). *Microdictyon setchellianum* was prevalent at sites LIS-12 and LIS-18 where it covered 11.2% and 20.8% of the substrate, respectively but was a minor component of the algal community at other sites (Table H.3.1.3.).

Table H.3.1.1.--Percent cover of algal functional groups at long-term monitoring sites at Lisianski Atoll.

Site	Macroalgae	Turf algae	Coralline red algae (crustose + upright)	Cyanobacteria	Coral
LIS-10	2.8%	30.0%	15.6%	-	51.6%
LIS-12	48.4%	18.8%	27.2%	0.4%	5.2%
LIS-18	54.4%	18.0%	8.4%	-	18.0%
LIS-R10	17.6%	14.0%	17.6%	-	50.8%
LIS-R14	29.2%	10.8%	13.2%	-	45.6%
LIS-R7	18.0%	17.6%	5.2%	-	59.2%

Table H.3.1.2.--Additional species recorded at each site at Lisianski Atoll during Roving Diver survey.

Site	<b>Chlorophyta</b>
LIS-R14, LIS-12	<i>Caulerpa taxifolia</i>
LIS-10, LIS-R14	<i>Caulerpella ambigua</i>
LIS-18, LIS-R10	<i>Dictyosphaeria cavernosa</i>
LIS-R14	<i>Halimeda discoidea</i>
LIS-10	<i>Halimeda velasquezii</i>
LIS-10	<i>Microdictyon setchellianum</i>
LIS-10, LIS-R10, LIS-R14	<i>Neomeris</i> sp.
	<b>Ochrophyta</b>
LIS-18	<i>Dictyota ceylanica</i>
	<b>Rhodophyta</b>
LIS-R7, LIS-R10, LIS-R14	<i>Amphiroa</i> sp.
LIS-R10	<i>Chondrophycus parvipapillatus</i>
LIS-12	<i>Coelarthrum</i> sp.
LIS-10	<i>Dasya iridescens</i>
LIS-12	<i>Haloplegma duperreyi</i>
LIS-R14	<i>Nemastoma</i> sp.
LIS-18, LIS-R7, LIS-R14	<i>Peyssonnelia</i> sp.

Table H.3.1.3.--Percent cover of macroalgal species at long-term monitoring sites at Lisianski Atoll. Sum totals for each row equal the percent cover of macroalgae recorded in Table H.3.1.1.

Site	<i>Caulerpella ambigua</i>	<i>Dictyosphaeria cavernosa</i>	<i>Dictyosphaeria versluisii</i>	<i>Halimeda discoidea</i>	<i>Halimeda opuntia</i>	<i>Halimeda velasquezii</i>	<i>Microdictyon setchellianum</i>	<i>Neomeris</i> sp.	<i>Lobophora variegata</i>	<i>Laurencia galtsoffii</i>	<i>Martensia</i> sp.	<i>Peyssonnelia</i> sp.
LIS-10	-	-	0.4%	0.4%	-	0.8%	-	-	1.2%	-	-	-
LIS-12	-	0.4%	1.2%	-	24.0%	10.4%	11.2%	-	0.8%	-	-	0.4%
LIS-18	-	-	2.8%	-	13.6%	10.0%	20.8%	-	5.2%	1.2%	0.8%	-
LIS-R7	0.4%	6.0%	1.2%	-	2.4%	3.2%	2.8%	0.4%	0.8%	-	-	-
LIS-R10	-	-	-	-	5.6%	5.2%	-	-	6.4%	-	-	0.4%
LIS-R14	-	-	-	-	11.2%	10.0%	3.2%	-	4.8%	-	-	-

### H.3.2. Corals

#### H.3.2.1 Coral Populations

Coral cover at Lisianski is moderately high with a mean of  $38.4 \pm 8.8\%$  according to line point intercept (LPI) surveys. Within the six forereef sites visited in 2008, corals of the genus *Porites* were the most abundant consisting of 82.6% of the island-wide coral composition (Table H.3.2.1.1.). Large mounding colonies of *Porites* (*evermanni* and *lobata*) and/or branching colonies of *Porites compressa* were common at most sites and members of the genus *Montipora* were observed to be more common at the three southwestern sites than at other sites (Fig. H.3.2.1.1.). Overall, 19 anthozoan species (18 scleractinian and 1 zoanthid) were found within belt surveys.

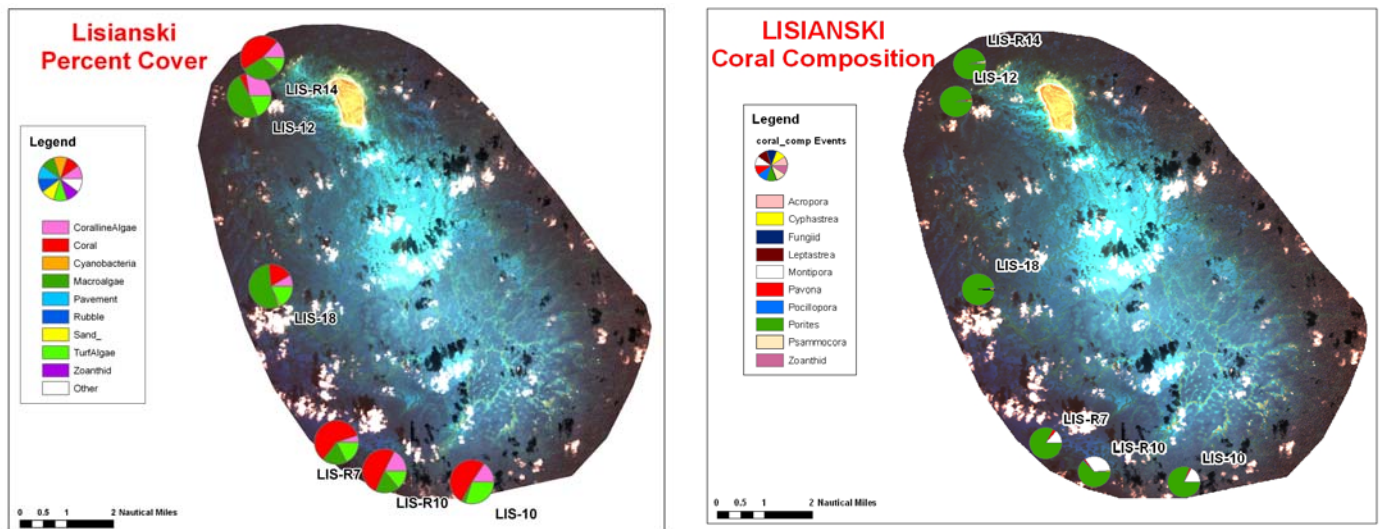


Figure H.3.2.1.1.--Spatial distribution of benthic cover and coral composition for REA sites at Lisianski in 2008.

Table H.3.2.1.1.--Relative percentage of coral taxon enumerated within belt transects for three habitat strata at Lisianski in 2008.

Forereef	
Taxon	Percent
<i>Porites lobata</i>	34.5
<i>Porites evermanni</i>	30.9
<i>Porites compressa</i>	17.2
<i>Montipora patula</i>	9.6
<i>Montipora capitata</i>	4.3
<i>Cyphastrea ocellina</i>	1.0
<i>Pavona maldivensis</i>	0.5
<i>Pavona varians</i>	0.5
<i>Pavona duerdeni</i>	0.4
<i>Pocillopora meandrina</i>	0.3
<i>Pocillopora damicornis</i>	0.2
<i>Psammocora stellata</i>	0.2
<i>Montipora</i> sp.	0.1
<i>Fungia scutaria</i>	0.1
<i>Pocillopora</i> sp.	0.1
<i>Montipora turgescens</i>	0.1
<i>Leptastrea purpurea</i>	0.0
<i>Porites</i> sp.	0.0
<i>Zoanthus</i> sp.	0.0
Unknown Scleractinian	0.0

#### H.3.2.2. Coral Disease

In 2008, coral communities at REA sites appear to be recovering from the substantial bleaching observed during September 2004 surveys. Prevalence of bleaching was relatively low overall, with the exception of mild to moderate bleaching observed in about 25% of the colonies of *Montipora capitata*, *M. patula*, and *Pavona duerdeni*. Numerous cases of compromised health states were noted involving algal interactions, *Porites* trematodiasis, discoloration, and tissue loss and were observed in colonies of the genus *Porites* (Fig. H.3.2.2.1.). Relative percent of live versus dead tissue of seven genera at Lisianski in 2008 are presented in Figure H.3.2.2.1.



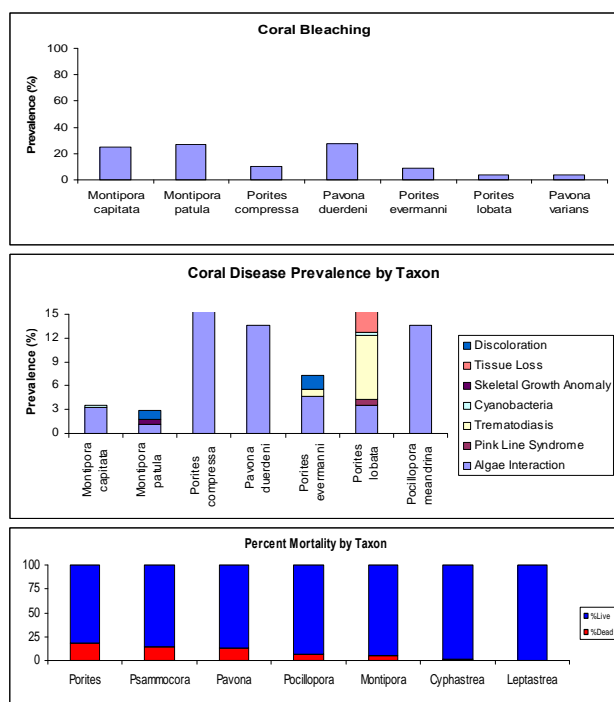


Figure H.3.2.2.1.--Top: Prevalence of bleached colonies for seven taxon at Lisianski. Middle: Prevalence of coral disease by disease state for seven coral taxa. Bottom: Relative percent of dead surface area for seven coral genera at Lisianski Reef.

### H.3.3. Non-coral Invertebrate Surveys

Non-cryptic macroinvertebrates were extremely low around the coral-dominated sites at Lisianski Island. A total of 201 individuals of benthic invertebrate target species or taxa group were enumerated from 12 belt transects at 6 sites. The boring urchins, *Echinostrephus aciculatus* and *Echinometra mathaei*, were the most abundant benthic macroinvertebrates at Lisianski. Densities were highest at sites LIS-18 and LIS-R14 (*E. aciculatus* 0.62 and 0.32/m<sup>2</sup> and *E. mathaei* 0.14 and 0.60/m<sup>2</sup>, respectively). With the exception of ophiuroids, other echinoderms, holothuroids, and asteroids were exceptionally rare. Although not quantified, *Ophiocoma pica*, was extremely abundant at sites LIS-12 and LIS-18 within non-geniculate coralline red algae and *Pessannelia* sp. Only one holothuroid, *Actinopyga obesa*, was observed at Lisianski and it was seen off transect. The invasive hydroid, *Pennaria disticha*, was observed on all the transect stakes minus those at site LIS-R10.

#### H.3.3.1. Urchin Measurements

Figure H.3.3.1.1. reveals the average test diameter of urchins encountered at each site. Only sites where  $\geq 5$  measurements were recorded for a species are represented.

Table H.3.3.1.1.--Mean test size of urchins by site.

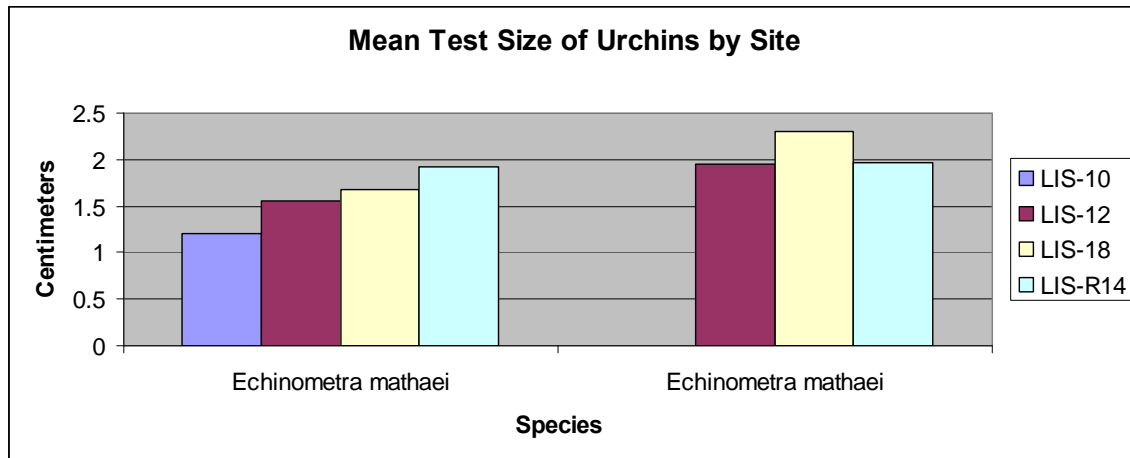


Table H.3.3.1.2. reveals the average test diameter of urchins by stratum. At Lisianski, only one stratum is represented, the forereef.

Table H.3.3.1.2.--Mean test size of urchins by stratum.

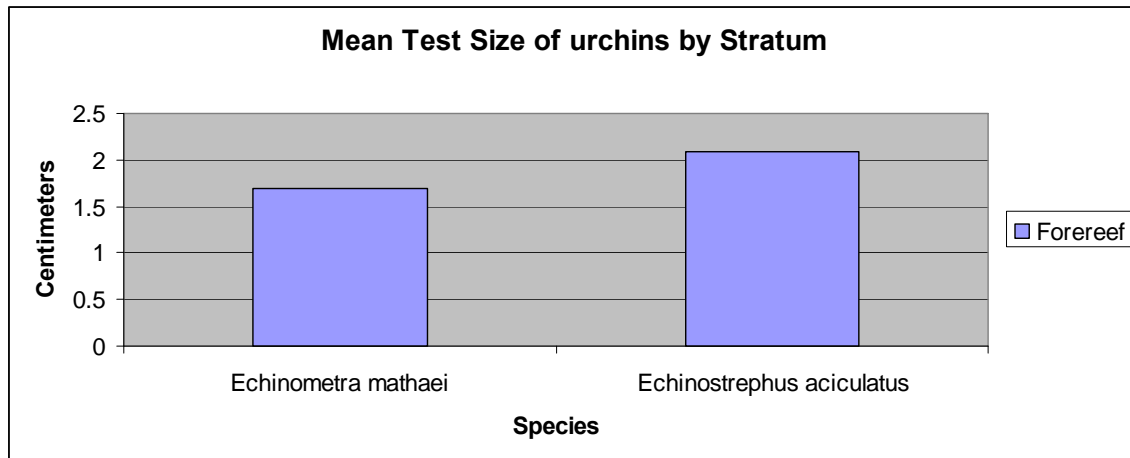


Table H.3.3.2. Autonomous Reef Monitoring Systems (ARMS) Deployment

ARMS were deployed at the following rapid ecological assessment (REA) sites around Lisianski Island. Each site contains three ARMS.

Table H.3.3.2.1.--ARMS deployment locations around Lisianski Island.

REA Site	Latitude	Longitude
LIS-R14	26° 04.692 N	-173° 59.82198 W
LIS-R9	26° 02.36802 N	-174° 00.74598 W
LIS-R10	25° 56.67102 N	-173° 57.21 W

#### H.3.4 Towed-diver Benthic Surveys

The 11 towed-diver benthic habitat surveys of Lisianski were conducted along the near-shore waters of Lisianski Island and the outlying patch reef habitat, encompassing the island and Neva Shoals. The overall averages for substrate composition and macroinvertebrate population densities are illustrated in the tables below (Table H.3.4.1., H.3.4.2.).

Table H.3.4.1.--Overall benthic habitat composition.

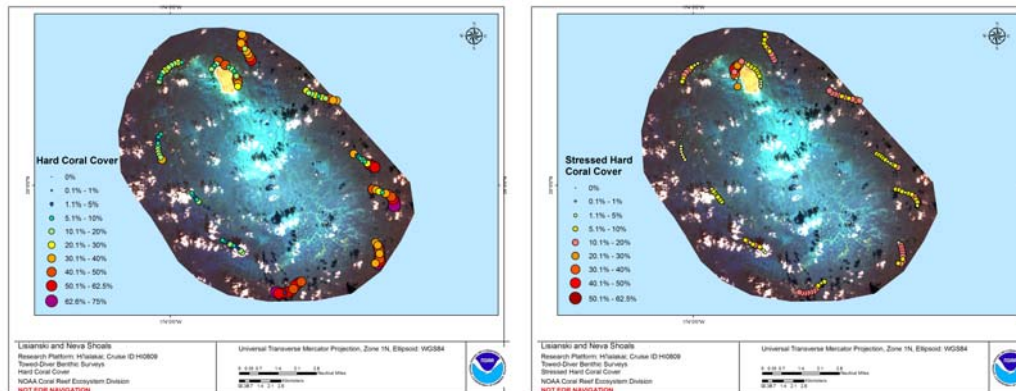
<b>Substrate</b>	<b>Percent Cover (%)</b>	<b>Percent Cover Range (%)</b>
Hard Coral	28.71	0–75
Stressed Hard Coral	10.80	0–50
Soft Coral	0.025	0–1
Sand	25.91	0–100
Rubble	3.38	0–40
Macroalgae	19.04	0–62.5
Coralline algae	18.26	0–50

Table H.3.4.2.--Overall macroinvertebrate population densities.

<b>Macroinvertebrate</b>	<b>Density (#/hectare)</b>	<b>Total # Observed</b>
<i>Acanthaster Planci</i> (COTs)	0	0
Boring sea urchins	0.50	1,384
Free-living sea urchins	0.004	7
Sea Cucumbers	0.005	10

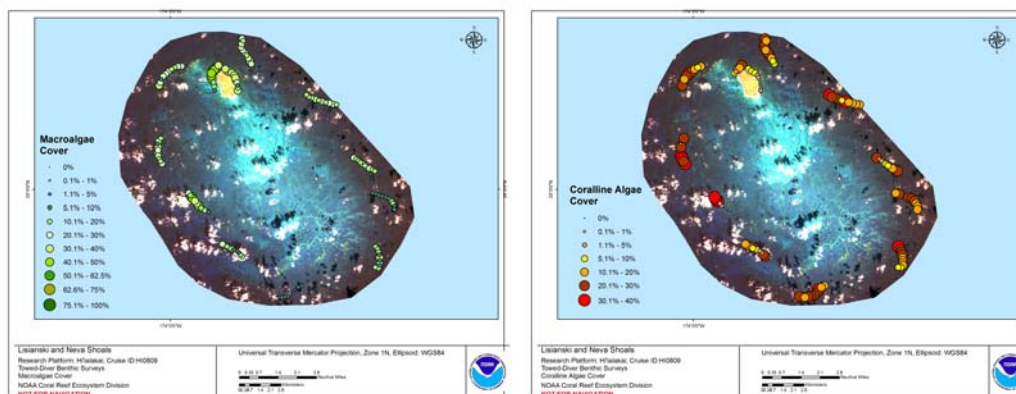
The nearshore habitat around Lisianski Island was made up of primarily continuous reef or small patch reef amongst sand flats. The surveys conducted along the outlying habitat of Lisianski Island and Neva Shoals indicated that these habitats were also made up of primarily continuous reef or patch reef of varying sizes and relief surrounded by sand flats.

Hard coral cover averaged 28.71% for the entire area. The highest coral cover was located along the entire southern section of Neva Shoals, in particular along the southwest side, where coral composition was primarily composed of *Porites lobata*, *Porites compressa*, *Porites evermanni*, and *Montipora*. Coral stress was moderate, averaging 10.80% overall. The greatest amount of stressed hard coral was observed along the western reef crest adjacent to the island, where a number of *Montipora* colonies were bleached.



Figures H.3.4.1. and H.3.4.2.--Hard coral and stressed coral cover.

Macroalgae cover averaged 19.04% overall and was highest along the western and northwestern areas of the shoals and island. *Halimeda* accounted for the majority of all macroalgae, with some patches of *Microdictyon*, *Neomeris*, *Asparagopsis*, and *Caulerpa*. Coralline algae cover averaged 18.26% overall and was highest in the northwest.



Figures H.3.4.3. and H.3.4.4.--Macroalgae and coralline algae cover.

Macroinvertebrate observations were sparse in all categories. Boring sea urchins were the most abundant with a total of 1384 individuals observed (0.5 per hectare). Most of the boring urchins occurred along the shallow pavement tops of the larger patch reefs, especially during the two surveys conducted in the northwest. Both free-living sea urchins and sea cucumbers were rarely observed during the 11 surveys. Free-living sea urchins totaled 7 with a density of 0.004 individuals per hectare, and sea cucumbers totaled 10 with a density of 0.005 individuals per hectare. No crown-of-thorns (COTs) were observed during surveys of Lisianski Island and Neva Shoals.

## H.4 Fish

### H.4.1 REA Fish Surveys

#### *Belt transect data*

During the survey period, 34 belt transect surveys were conducted at 14 sites around Lisianski and Neva Shoals. Jacks (Carangidae) were, by far, the largest contributor to total biomass with 18.11 kg 100 m<sup>-2</sup>. Surgeons (Acanthuridae) were the second largest contributor to total biomass with 2.23 kg 100 m<sup>-2</sup>, followed by parrotfish (Scaridae) at 2.07 kg 100 m<sup>-2</sup> (Table H.4.1.1.).

#### *Overall observations*

A total of 78 fish species were observed during the survey period by all divers. The average total fish biomass at the sites at Lisianski and Neva Shoals during the survey period was 15.87 m<sup>-2</sup> for the belt transect surveys (Table H.4.1.2.).

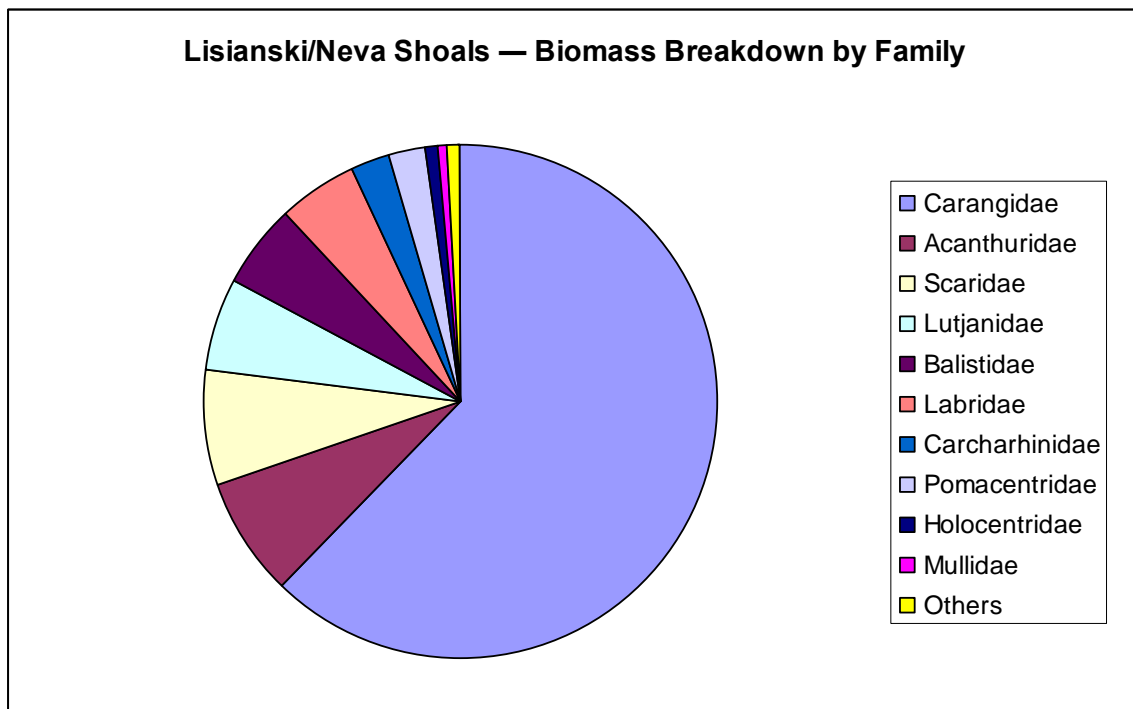


Figure H.4.1.1.--Total fish biomass composition by family.

<b>Table H.4.1.2.--Coral reef fish biomass (kg 100 m<sup>-2</sup>) at sites around Lisianski/Neva Shoals.</b>													
<b>Stratum – Depth</b>	<b>Site</b>	<b>Total</b>	<b>Acanth.</b>	<b>Balistid</b>	<b>Carangid</b>	<b>Carchar.</b>	<b>Holocen.</b>	<b>Labrid</b>	<b>Lutjanid</b>	<b>Mullid</b>	<b>Pomacen.</b>	<b>Scarid</b>	<b>Other</b>
Forereef – Mid	LIS-10	26.62	0.35		18.87		0.02	1.41	3.33	0.05	1.30	1.20	0.10
	LIS-12	15.51	5.92		1.54			1.15	2.30	0.24	0.08	3.54	0.73
	LIS-126	5.46	0.26	0.27	1.13		0.58	0.92			0.41	1.74	0.15
	LIS-208	28.38	0.42	0.30	24.11		0.11	0.56	1.99		0.52	0.27	0.10
	LIS-209	26.27		11.85	6.66	5.88		0.58			0.86	0.39	0.05
	LIS-R10	46.82	0.87		40.48		1.01	1.01	0.81	0.04	0.50	1.92	0.18
	LIS-R14	9.20	1.34					0.92	2.17	0.05	0.17	4.08	0.48
	LIS-R7	30.65	0.00		26.70			0.67	0.81		1.01	1.41	0.04
Forereef – Shallow	LIS-18	16.51	4.54		7.10			1.38	1.73	0.40	0.15	1.13	0.08
	LIS-201	3.82	0.43		3.20			0.04				0.08	0.06
	LIS-202	0.43	0.00				0.01	0.23		0.01	0.02	0.12	0.04
	LIS-203	5.38	0.58		3.78			0.73			0.13	0.10	0.07
	LIS-502	5.09	0.04		4.44			0.39		0.04	0.07	0.06	0.05
	LIS-503	2.04	0.90		0.53			0.48		0.02	0.06	0.04	0.02
<b>Average</b>		<b>15.87</b>	<b>1.20</b>	<b>4.14</b>	<b>11.54</b>	<b>5.88</b>	<b>0.34</b>	<b>0.75</b>	<b>1.88</b>	<b>0.10</b>	<b>0.41</b>	<b>1.15</b>	<b>0.15</b>

#### H.4.2 Towed-diver Fish Surveys

During the 2008 Reef Assessment Monitoring Program mission, the Coral Reef Ecosystem Division's (CRED) towboard team completed 12 surveys at Lisianski Island covering 24.7 km (24.7 ha) of ocean floor (Table H.4.2.1.). Mean survey length was 2.1 km with a maximum length of 2.3 km and a minimum of 1.7 km. Mean survey depth was 10 m with a maximum depth of 14.2 m and a minimum of 1.6 m. Mean temperature on these surveys was 28 °C with a maximum temperature of 28.2 °C and a minimum of 27.8 °C.

Table H.4.2.1. --Survey statistics for towboard sampling during HI-08-09.

Island/Atoll/Reef	#	Length (km)					Depth (m)				Temperature (°C)			
		Sum	Mean	Max	Min	SD	Mean	Max	Min	SD	Mean	Max	Min	SD
Kure	14	32	2.3	2.7	1.8	0.02	8.2	16.5	0.9	5.9	26.8	27.3	25.5	0.4
Midway	16	39	2.4	3.2	1.9	0.03	9	16.9	0.7	5.9	27.2	28	26.9	0.3
Pearl & Hermes	27	63	2.3	3.1	1.3	0.03	10.3	16.3	1.2	5.2	27.3	27.9	26.8	0.3
Lisianski	12	24.7	2.1	2.3	1.7	0.02	10	14.2	1.6	3.9	28	28.2	27.8	0.1
Laysan	5	11.5	2.3	2.5	2.1	0.01	11.8	13.6	9.2	1.5	27.9	28	27.8	0.1
Maro Reef	11	23.4	2.1	2.4	1.7	0.01	13.3	16.5	9.5	1.8	28.2	28.4	27.9	0.1
French Frigate	26	56.5	2.2	2.9	1.4	0.03	11.5	17.1	1.8	4.5	27.6	28.3	26.9	0.2

Forty-eight individual large-bodied reef fish (> 50 cm TL) of six different species and five families were encountered at Lisianski Island (Table H.4.2.2.). Overall numeric density for this class of reef fishes was 0.0194 #/100 m<sup>2</sup> (1.943 #/ha) with a biomass density of 0.1077 kg/100 m<sup>2</sup> (0.0108 t/ha). Numeric density was dominated by *Caranx melampygus* which was encountered in near the north end of the island and along the southeastern margin of Neva Shoals. Biomass density was dominated by *Caranx ignobilis* which was seen individually or in small schools of 2–5 individuals mainly on the western side of the shoals.

At the family level, Carangids, and Lutjanids made up 69% and 25% of the overall numeric density (Fig. H.4.2.1.) and 81% and 17% of the biomass density (Fig. H.4.2.2.).

Large reef fish biomass at Lisianski was highest along the western margin of Neva Shoals and at the north end of Lisianski Island itself. Along the southeastern margin of Neva Shoals, coral communities appeared to be quite extensive with high rugosity levels; however, communities of both large and small reef fishes appeared depauperate.

Table H.4.2.2.--Species numeric and biomass density for large-bodied reef fish (> 50 cm TL) observed at Lisianski Island during 2008 CRED towed-diver surveys.

Species	#	#/100m2	#/ha	Biomass (kg)	kg/100m2	t/ha
Aetobatus_narinari	1	0.0004	0.0405	2.1700	0.0009	0.0001
Aprion_virescens	12	0.0049	0.4859	44.0821	0.0178	0.0018
Aulostomus_chinensis	1	0.0004	0.0405	0.1964	0.0001	0.0000
Caranx_ignobilis	12	0.0049	0.4859	148.2707	0.0600	0.0060
Caranx_melampygus	21	0.0085	0.8503	68.7264	0.0278	0.0028
Naso_unicornis	1	0.0004	0.0405	2.5675	0.0010	0.0001
Grand Total	48	0.0194	1.9436	266.0131	0.1077	0.0108
# of Species	6					

**Numeric Density Contribution by Family for Large-Bodied Reef Fish (>50cmTL) observed at Lisianski Island During 2008 CRED Towed-Diver Surveys**

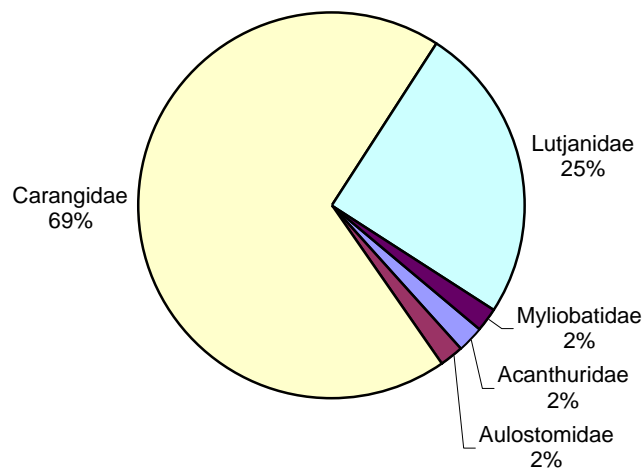


Figure H.4.2.1.--Numeric density by family.



**Biomass Density Contribution by Family for Large-Bodied Reef Fish (>50cmTL)  
observed at Lisianski Island During 2008 CRED Towed-Diver Surveys**

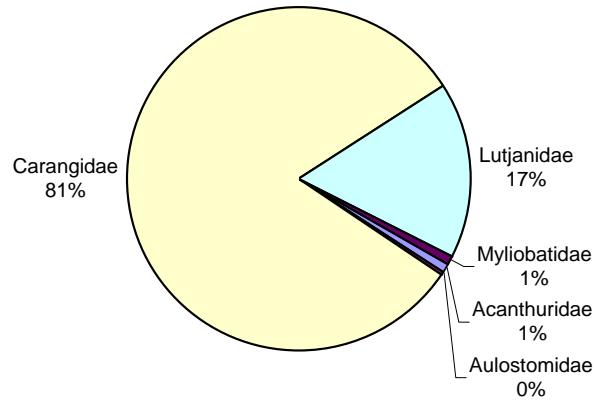


Figure H.4.2.2.--Biomass density by family.

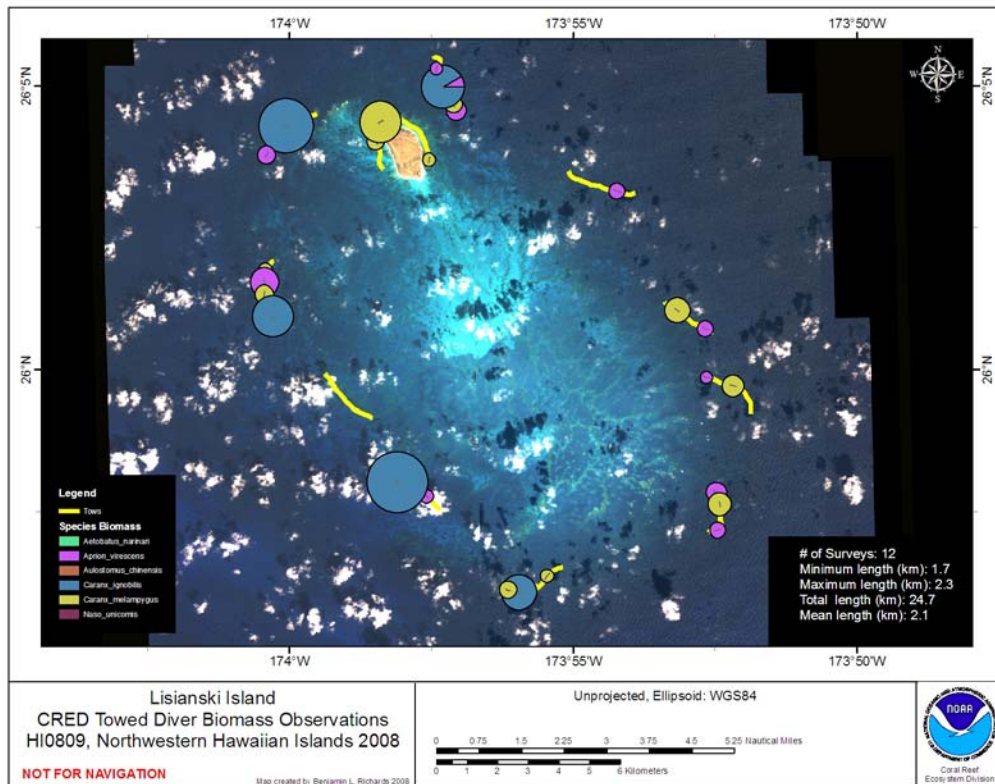


Figure H.4.2.3.--Geographic distribution of biomass around Lisianski Island. Each species is represented by a legend color. Diameter of pie chart is proportional to total biomass of all species encountered on the underlying survey.